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W. G. WALL, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

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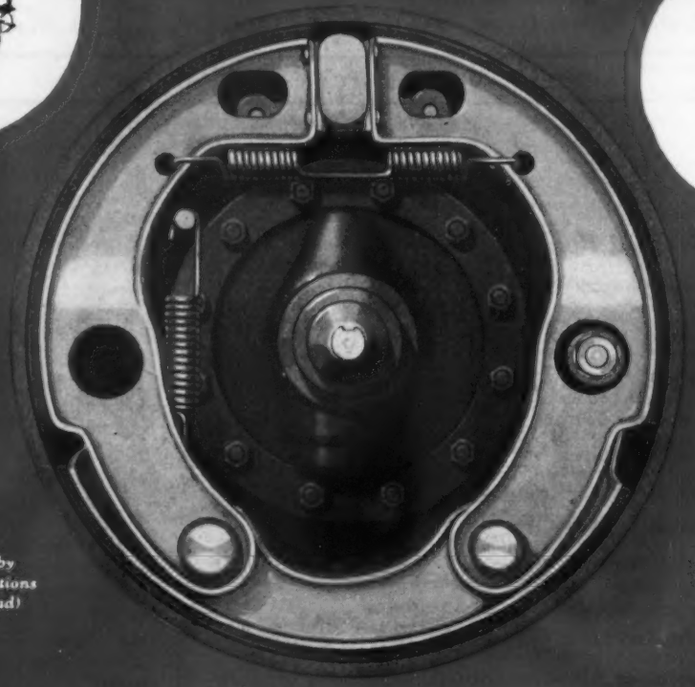
The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.



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S. A. E. JOURNAL

Vol. XXIII August, 1928 No. 2

Six Society Meetings Scheduled

Technical Programs Now Being Arranged by Committees for Aeronautic, Transportation and Production Meetings

THE calendar of Society meetings, given on the following page, received final approval by the Meetings Committee and the Council during the Summer Meeting at Quebec, and the Technical Program Committees are now outlining the technical sessions and arranging for the papers that will be given at these various meetings.

Members interested in the professional activities of the Society that are being featured by the several meetings planned are urged to communicate with the chairmen of the technical committees. Only with the full cooperation of the membership can technical programs be prepared that will warrant the amount of time and expense involved in preparing for, conducting and attending the technical meetings.

A classification of the membership of the Society is given in this issue in Chronicle and Comment, p. 131. From this classification it will be realized that a large percentage of the membership is directly interested in the Aeronautic, Transportation, and Production Meetings scheduled. The entire membership is interested in each of them to some extent, no doubt, but it is recognized that active support of the meetings activities must come from the members directly concerned. Those who desire to get in touch with the chairmen of the technical committees are invited to do so promptly through the Meetings Department of the Society or to communicate directly with the chairmen.

Aeronautic Meetings

The Western Aeronautic Meeting will be held in Los Angeles on Sept. 11 and 12, at the time and place of the National Air Races. Papers have been promised by C. S. Moody, of the Pacific Scientific Co.; J. K. Northrop, of the Lockheed Aircraft Co.; George H. Prudden, of the Prudden-San Diego Airplane Co.; Mac Short, of the Stearman Aircraft Co.; H. V. Thaden, of the Thaden Metal Aircraft Corp.; Waldo N. Waterman and James G. Woolley, of the Western Air Express Co., Inc., and Commander E. E. Wilson. Commander Wilson's paper will deal with the relation of battle tactics to design technique.

Local arrangements for this meeting are being made by Ethelbert Favary, a member of the Aeronautic Meeting Committee, of which Glenn L. Martin is chairman. Other members of the committee are the Hon. E. P. Warner, L. M. Woolson and Earl D. Osborn.

It is expected that a session of the Aeronautic Standards Division will be held at the meeting to carry forward the important program of aeronautic standardization which was reported in the June issue of THE JOURNAL, p. 697, and on p. 203 of this issue.

Meetings Bulletins giving detailed information regarding the Los Angeles meeting will be mailed to members during the next few weeks.

The Eastern Aeronautic Meeting is to be held in Chicago on Dec. 6 and 7. The Aeronautic Meeting Committee has outlined a comprehensive program for the Chicago sessions.

The Aeronautic Operation Dinner-Meeting will be held in New York City during the week of the Automobile Show. The date will be decided shortly.

Transportation Meeting

At a meeting of the Transportation Meeting Technical Program Committee held in New York City on July 18, a tentative technical program was decided upon. The committee consists of F. C. Horner, chairman; H. F. Bacon, W. F. Banks, H. R. Cobleigh, C. J. Fagg, F. K. Glynn, A. W. Herrington, E. F. Loomis, A. D. Way and J. F. Winchester. Seven technical sessions are planned for the three days, Oct. 17 to 19, together with a Transportation Banquet on the evening of Oct. 18. The meeting will be held at the Robert Treat, Newark, N. J.

Production Meeting

Under the chairmanship of E. P. Blanchard, the Technical Program Committee for the Production Meeting is rounding out the technical sessions for Nov. 22 and 23, which will be held at the Book-Cadillac, Detroit. Members of the committee, in addition to Mr. Blanchard, are: J. B. Armitage, A. H. Fors, G. Walker Gilmer, Jr., Guy Hubbard, Erik Oberg and John Younger. Members primarily interested in production have been asked by Chairman Blanchard to suggest subjects and speakers for consideration by the Committee. Only by making the program cover the problems that confront the production engineers today can a program be arranged that will attract to the meeting the production engineers and executives who are qualified to discuss the various problems.

Annual Dinner

The Annual Dinner Committee is making plans, under the chairmanship of Sidney R. Dresser, for a dinner that will be decidedly different from recent Annual Dinners. The feature of the dinner on Jan. 10 will be, according to present plans, a short humorous playlet, the talent being drawn from Broadway.

1929 Summer Meeting

At the Meetings Committee meeting at Quebec, the location for the 1929 Summer Meeting was discussed, possibilities mentioned including French Lick Springs, White Sulphur Springs, Spring Lake, Atlantic City, and an ocean cruise. No final action was taken. The Meetings Committee would appreciate receiving suggestions and opinions as to the 1929 Summer Meeting, as it is necessary to make definite hotel arrangements in the near future.

1928 Summer Meeting Papers

Members desiring copies of any of the papers presented at the Summer Meeting reported in the news account of the Quebec meeting in the July issue of the S.A.E. JOURNAL should communicate with the office of the Society, as a limited number of preprinted and mimeograph copies of the papers are available for distribution.

Meetings Calendar

Western Aeronautic Meeting
Sept. 11 and 12, 1928
Biltmore Hotel, Los Angeles

Transportation Meeting
Oct. 17 to 19, 1928
The Robert Treat, Newark, N. J.

Production Meeting
Nov. 22 and 23, 1928
Book-Cadillac Hotel, Detroit

Eastern Aeronautic Meeting
Dec. 6 and 7, 1928
Chicago

Aeronautic Operation Meeting
January, 1929
New York City

Annual Dinner
Jan. 10, 1929
New York City

Annual Meeting
Jan. 15 to 18, 1929
Book-Cadillac Hotel, Detroit

Chronicle and Comment

Curtailed S.A.E. Service in August

DURING the 2 weeks from Aug. 6 to 20 the office of the Society in New York City will be maintained by a mere skeleton of the staff while all the rest of the employes take a simultaneous vacation. A few employes will be in attendance to handle incoming matters of importance that require immediate attention. In general, however, the office will be regarded as closed for the period.

How Society Membership Is Constituted

A CLASSIFICATION that has been made of the membership of the Society should be of interest to the members in general, as well as helpful to the officers, councilors and committee chairmen and members in planning the activities of the Society.

Based on the nature of the work in which they are engaged, the 6649 members, as of May 1, 1928, including enrolled students, are interested primarily in the several lines of engineering in the percentages below.

CLASSIFICATION BY WORK

	Per Cent
Design and Research	32
Executive Management	24
Sales	13
Production	12
Operation and Maintenance	8
Miscellaneous	11
	100

Another classification of interest is that according to product of the companies with which the members are associated.

CLASSIFICATION BY PRODUCT

	Per Cent
Chassis Parts and Engines	34
Passenger-Cars	12
Motor-Trucks and Fire Apparatus	8
Raw Materials and Unfinished Parts	7
Education	7
Aircraft	4
Industrial Engines and Machinery	4
Machine-tools	4
Motorcoaches	2
Bodies	2
Tractors	2
Motorboat	1
Miscellaneous	13

Financial Policy of the Society

THE question as to what the financial policy of the Society is has been asked repeatedly recently. Many of the members, seeing an increasing reserve each year, seem to think that this money might be used at once for various purposes. As Treasurer of the Society I desire to make the following statement.

During the early years of existence of the S.A.E. its objects of standardization and promoting engineering interests were so overwhelming that it was difficult to build up membership and funds to support this work, which has saved the industry incalculable dollars, and has been a guiding and sustaining artery of its present accomplishments.

Only within recent years have there been surplus funds—which have accumulated through increase in membership, appreciation of the advertising value of the S.A.E. JOURNAL and careful management of the details of the organization. Such funds as have accumulated are not the result of a definitely arranged policy to build up a surplus but of a gradual accumulation of savings beyond such expenditures as were necessary to maintain the Society's high standards.

Ten years ago, when I was elected Treasurer of the Society, there was approximately $35,000 unexpended income. Five years ago, when the unexpended income had grown to $100,000, I felt that it should be under the custodianship of one of the soundest trustees that could be selected. The Chemical National Bank of New York was chosen, and only investments legal for trust funds in Connecticut and New York were made. The unexpended income has increased to over $200,000. Meantime thoughts have developed in the minds of its guardians, How much should this fund be allowed to grow? Why should it be allowed to grow? How should it be expended for the best interests of the Society and its members? In other words, What is the financial policy of the S.A.E.?

The only financial policy the S.A.E. now has is to conserve the highest interests of the Society and the intrinsic value of THE JOURNAL, so that the young engineers of today will join and reap the greatest good from membership and the S.A.E. JOURNAL continue to be the most direct and best advertising medium for both its advertisers and readers.

It must be borne in mind that the Society was organized for the purpose of promoting the engineering interests of the industry and not for profit. At the same time, the fact must not be overlooked that the greater the organization and its activities, the greater the need for its protection against days when, due to conditions beyond its control, its income might be curtailed, so that the organization will not be disrupted or destroyed and the returns to its members reduced to such an extent that the Society would lose its value to its members.

Every well-organized enterprise has its "reserve fund" in some form for its protection and to assure its continuity.

The present unexpended fund is approximately half of our yearly turnover. This amount can neither be considered excessive nor be viewed as adequate for all future needs. The amount for the future can best be determined by the growth and activities of the Society as they appear and by the general economic conditions of the industry. But there should be a gradual increase in the reserve fund of the Society each year to guarantee the continuance, stability and increasing interests and value to its present and future members.

Owing to the fact that the Society's structure involves yearly changes of its administrators, its policies can hardly help varying in accordance with the various ideas of the individuals who hold office. Necessarily it is difficult at any time to settle upon any plan more definite than to maintain the basis of ever taking care of the Society's best interests in accordance with its growth.—C. B. Whittelsey, treasurer.

The Synchrometer for Brake Testing

By CHARLES F. SMITH[1]

NEW ENGLAND SECTION PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

PROPER brake testing is stated to involve the measuring and recording of vehicle deceleration and rate of speed for every foot of individual wheel travel during the period from the initial application of the brakes up to the moment the car comes to a standstill.

The brake synchrometer, designed to duplicate the conditions under which a vehicle is tested on the road, embodies the principle of traction between each tire of the vehicle, on one hand, and a rotor on the other hand. The kinetic enegery of the four testing rotors must be equal to the energy of a vehicle of a certain weight at a given testing speed.

The author describes a brake synchrometer designed for testing vehicles of 3500-lb. weight, which machine, however, is adjustable to compensate for greater or lesser car weight, so as to include heavier or lighter vehicles in its test range. He explains the method of testing all the brakes of a vehicle individually at the same time, or of measuring and recording the combined capacity of the four brakes.

By an electrical method, accurate records are obtainable of the average speed in miles per hour of each wheel for each foot of travel during the braking period. These records serve as a basis for distance-speed curves, giving percentage readings of deceleration-rate variation.

The plotting of curves showing differences in synchrometer operating speed required to compensate for differences in vehicle weight is described, and experiences are given to illustrate the operation of the brake synchrometer in practice.

THE brake synchrometer was developed with the definite idea that a true brake-testing machine must test vehicle brakes under road operating conditions; that is, the same velocities, tire distortions, chassis stresses and brake-shoe pressures must be reproduced faithfully and the resultants measured and recorded.

The brake synchrometer shown in Fig. 1 is the only brake-testing machine on the market for testing brakes in this way, and it is the only machine that automatically makes a permanent record of the decelerating characteristics of each individual wheel, plotting the wheel's rate of speed for each foot of travel throughout the decelerating period.

The basic principle of the brake synchrometer is the law that a flywheel, revolving at a given speed, possesses a definite kinetic energy; also, given a plurality of duplicate flywheels run at the same speed, all will possess exactly the same energy and will be able to overcome or absorb precisely the same resistance to their movement. The construction and operation of the brake synchrometer are founded on the foregoing facts.

A certain well-known car weighing 4600 lb., which is advertised as having a 72-hp. engine, requires 18 2/5 seconds to accelerate from a standstill to 25 m.p.h., according to tests made by its manufacturer. Its brakes will bring this car to a standstill from a speed of 25 m.p.h. in 3 sec. or less, the brakes having to absorb and dissipate the output of the 72-hp. engine in one-sixth the time the engine develops it, or at a rate of 100 to 400 h.p. That is what the brakes must do on the road, and our contention is that they must be tested under identical conditions.

Accustomed to seeing spectacular pick-ups and sudden stops, few of us appreciate the terrific stresses involved, especially those inflicted on frames, springs, tires, and brake mechanisms, as well as the high temperatures which exist momentarily during deceleration at the braking surfaces. This temperature, according to a brake-lining manufacturer, runs from 1200 to 2000 deg. fahr. during braking in a fairly sudden stop.

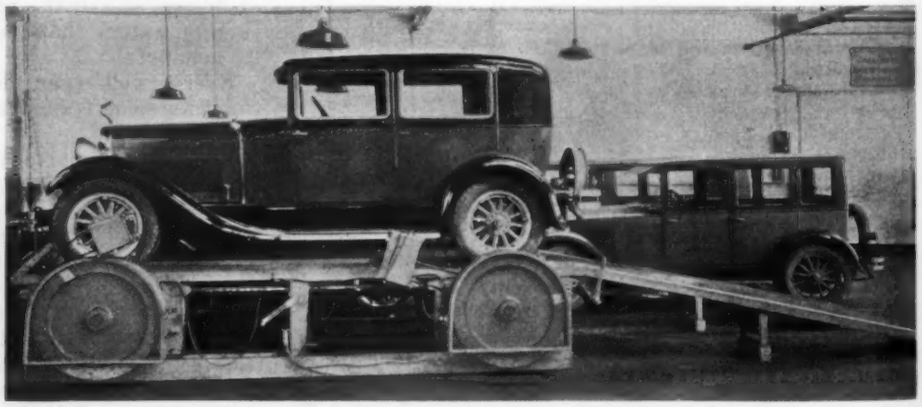

FIG. 1—THE BRAKE SYNCHROMETER, WITH CAR IN POSITION

The Momentum Rotors, below the Car Wheels, Are Driven by Drums on Which the Wheels Turn. The Drums Are Interconnected So That All Four Are Driven by the Rear Drive-Wheels of the Car. When a Predetermined Speed Is Attained, the Car Clutch Is Disengaged and the Brakes Applied. A Solenoid Automatically and Simultaneously Disconnects the Four Rotors So That They Revolve Independently by Their Own Momentum, and an Instrument Records the Stopping Distance of Each Car Wheel. The Total Braking Effect Is Determined from the Collective Results Obtained from the Brakes on All the Wheels

[1] Chief engineer, Brake Synchrometer Co., Boston.

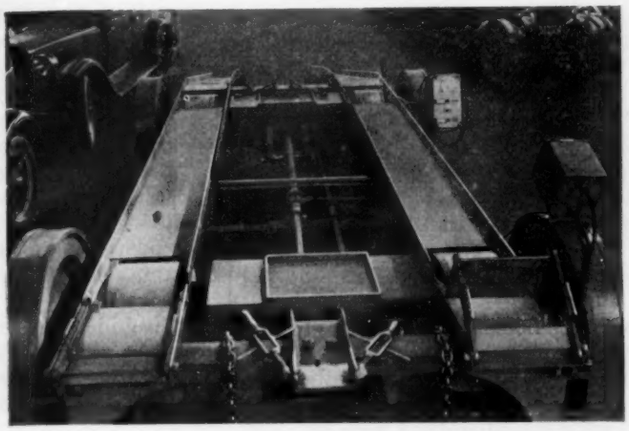

FIG. 2—THE SYNCHROMETER FROM THE REAR

This Shows Plainly the Relation of the Rotors, Drums and Connecting Shaft. Turnbuckle Car-Anchors Are Seen at the Rear and Front Center. Recording Instruments Are Contained in the Two Cases Mounted on the Rotor Guards on the Right

The brake synchrometer measures and records the effect of these stresses and temperatures on deceleration, not only for the vehicle as a unit, but for each wheel individually and for each foot of its travel throughout the decelerating process. An automobile in motion possesses energy in a definite amount that is dependent upon the weight and velocity of the vehicle. To bring the vehicle to a stop, its brakes must absorb and dissipate this energy, chiefly in the form of heat and at a rate approximately proportional to the rate of deceleration of its braking surfaces. If this rate can be maintained with the car held stationary when the brakes are applied, for instance, through the medium of a moving roadbed or track possessing the same energy that the vehicle possessed when moving at equal speed, the effects noted will be precisely the same that occurred when the brakes were applied with the vehicle in motion. This is the underlying principle of the brake synchrometer.

The testing machine consists mainly of four flywheels, or rotors, mounted in bearings and capable of being positively engaged with one another and rotated in unison, or of being disengaged from one another and free to rotate independently in accordance with such forces as may be brought to bear upon them independently. Each wheel of the vehicle rests upon a drum which is connected directly to one of these rotors. These drums can be seen plainly in Fig. 2. The flywheels are engaged with one another and the engine and gearshift of the automobile are operated exactly as though on the road. The engine and drive wheels are accelerated until the combined mass of the four rotors possesses the same kinetic energy that the vehicle under test possesses when it is operated on the road at a speed selected for testing.

COMPENSATING FOR DIFFERENCES OF WEIGHT

Arbitrarily, the flywheels of the brake synchrometer have been designed dynamically for normally testing a vehicle weighing 3500 lb.; that is, in testing a vehicle of that weight, the rotors are run at the speed at which it is desired to test the brakes of the vehicles. Heavier cars are run at a slightly higher speed, and vehicles weighing less than 3500 lb. at a correspondingly slower speed, the total energy of the flywheels being in either event the same as that of the vehicle at the testing speed.

In operation, a man determines the weight of a car and operates it on the brake synchrometer. When the testing speed is reached, the brakes are applied. The rotors are simultaneously and automatically disconnected from one another and the recording instruments are set in motion, registering independently the number of feet and inches each wheel travels before it comes to rest.

When the brakes are applied, each brake has the task of arresting the movement of an independently revolving flywheel, the kinetic energy of which equals one-fourth that of the vehicle under test when operated on the road at the selected speed. Therefore, in arresting the rotation of the individual rotors through the medium of the respective brakes, the functioning ability of each wheel brake is tested and graphically recorded. The total braking effect possessed by the vehicle under test is determined from the collective results obtained from the brakes on all the wheels.

For service-station work, the brake synchrometer usually is provided with an odometer for each wheel, to record in feet and fractions of feet the distance traveled by each wheel after the brakes are applied. For the use of brake engineers and others who require a close study of brake action, a small electric attachment records the brake action of a vehicle on a tape, as shown in the lower part of Fig. 3.

When the brakes are applied, the tape is passed under four electrodes, one for each wheel, by a small synchronous motor at a speed of 6 in. per sec. Cams

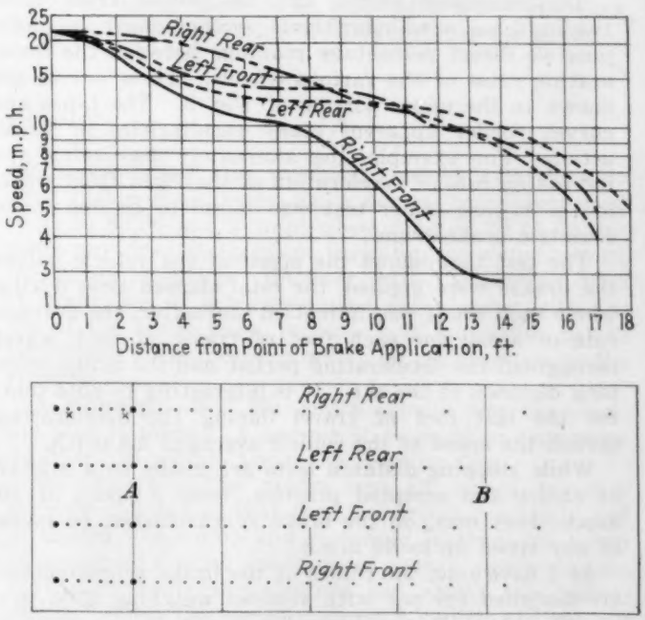

FIG. 3—TAPE RECORD AND BRAKING CURVES PLOTTED FROM IT

Below Is an Actual Record of the Braking Effect on Each Car Wheel. This Is Made by an Electrical Instrument and the Space between Each Two Dots Represents 1 Ft. of Wheel Travel. The Average Speed for Any Particular Foot of Travel Is Read Directly in Miles per Hour by Measuring the Length of the Space, and Distance-Speed Curves, as Shown Above, Can Be Plotted from the Readings

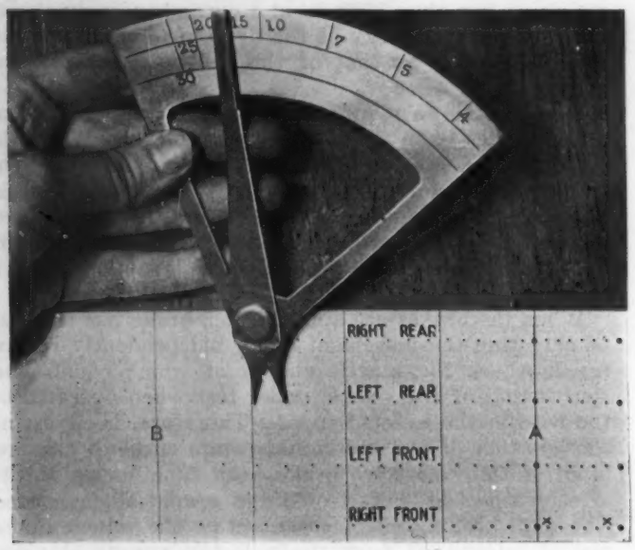

FIG. 4—INSTRUMENT FOR READING SPEED FROM TAPE RECORD
The Interval between Dots at the Lower Points of the Instrument Represents the Time for 1 Ft. of Wheel Travel. This Is Read in Miles per Hour on the Scale at the Upper End of the Movable Arm

on each rotor shaft operate breaker mechanism timed to pass a high-tension spark through the paper at each foot of wheel travel. As each space between two dots represents 1 ft. of road travel, the average speed for any particular foot of travel is read directly in miles per hour by measuring the length of the corresponding space with the instrument shown in Fig. 4.

Distance-speed curves can be plotted from these readings, on semi-logarithmic section paper, to make possible direct percentage readings between the decelerating rates of the various wheels. These curves are shown in the upper portion of Fig. 3. The tapes and curves render apparent many peculiarities of brake action. For example, the alternately decreasing and increasing rate of deceleration of the right front wheel of the vehicle under test was found to be due to an eccentric brake-drum.

The test tape shows the speed of the vehicle before the brakes were applied, the total elapsed time during which each wheel was in motion thereafter, the average rate of speed for each foot of travel of each wheel throughout the decelerating period, and the actual stopping distance of the car. It is interesting to note that, for the last foot of travel during the decelerating period, the speed of the vehicle averaged 2.5 m.p.h.

While stopping-distance tests are made, as a matter of choice and accepted practice, from a speed of 20 m.p.h., they may, on the brake synchrometer, be made at any speed up to 35 m.p.h.

As I have said, the rotors of the brake synchrometer are designed for par with vehicles weighing 3500 lb.; that is, when the synchrometer is run at any testing speed, the rotors possess exactly the same kinetic energy that a 3500-lb. vehicle would possess when driven on the road at that speed. However, if the vehicle under test weighs more or less than 3500 lb., a parallel increase or decrease in the kinetic energy of the rotors must be made.

The solid-line curve in Fig. 5 shows the difference in synchrometer speed required to compensate for the difference in vehicle weight. The data for this curve were obtained as follows: Three vehicles, weighing 2300, 3500 and 4800 lb. respectively, were used. Exacting attention was given in each case to car weight, speedometer accuracy, and brake-drum temperatures during the tests. A brake-pedal stop was installed on each vehicle, to assure the same degree of brake-shoe pressure every time the brakes were applied. On each of these cars a red-lead gun was clamped on the running-board 6 in. from the ground, and the trigger was connected with the brake-pedals.

We selected a stretch of road that provided a very high frictional coefficient, checked the speedometers, and made tests in both directions so as to average the windage and grade effects, and determine a consistent road-stopping distance.

To determine a definite stopping-point, we set the pedal-stops on the cars having the red-lead gun at a point at which the brakes would not skid the tires on the road. Over a large number of tests we thus obtained a consistent stopping distance for each of the three vehicles. I do not recollect any stopping distance that varied 3 in. in testing a car under these conditions. The vehicles were tested successively on the synchrom-

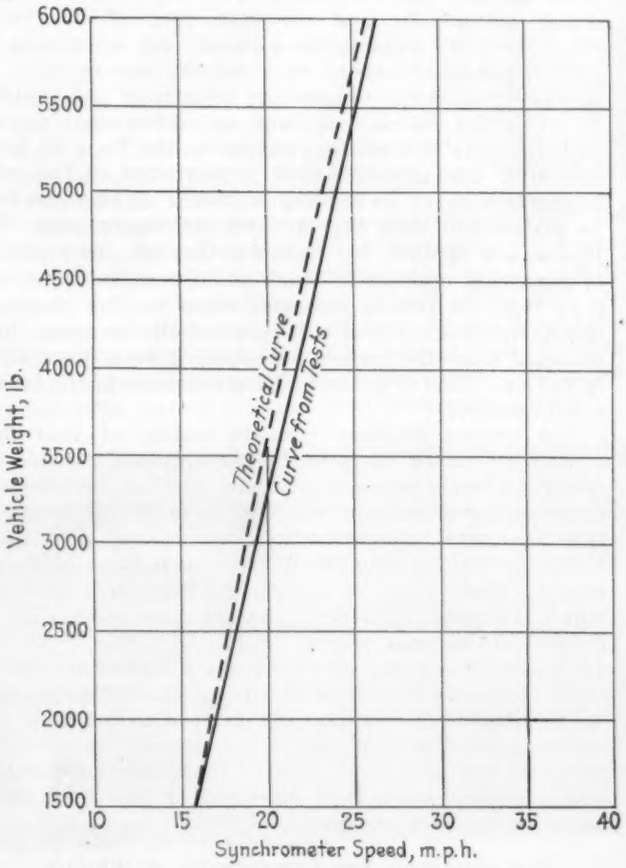

FIG. 5—ACTUAL AND THEORETICAL CURVES OF SYNCHROMETER SPEED REQUIRED FOR VEHICLES OF DIFFERENT WEIGHTS
The Solid-Line Curve Was Plotted from Actual Tests of Three Vehicles Weighing Respectively 2300, 3500 and 4800 Lb. The Broken-Line Was Plotted as a Theoretical Weight-Speed Curve by a Disinterested Engineer from Rotor Dimensions and Weights Given Him. A Difference of Only 0.75 M.P.H. Exists between Theory and Practice

eter at various speeds until a speed was found for each vehicle that gave the same stopping distance as was secured in our road tests. The limit of accuracy possible with the synchrometer is set by the ability of the operator to read the speedometer. No mathematical calculations are required in interpreting the results of a synchrometer test. The operator determines from the plotted curve the speed required for testing a vehicle of a certain weight, then makes his test and reads the result directly in feet and fractions of feet, which, when averaged, equals the stopping distance on the road of the vehicle tested.

Some time after developing this weight-speed curve we gave our flywheel dimensions to a disinterested engineer and asked him to plot a theoretical weight-speed curve. His curve is shown by the broken line in Fig. 5, the solid line showing our own curve. A difference of only 0.75 m.p.h. existed between theory and practice.

Description of Brake Synchrometer

Our machine, suitable for cars of 96 to 160-in. wheelbase, weighs about 7000 lb. It is 16 ft. long, 7 ft. 8 in. wide and 24 in. high. A lighter machine for testing smaller cars and a heavier machine for trucks and motorcoaches are in process of construction. Originally, as our machine stood rather high, we made every effort to reduce the height; but when it was installed in a number of service stations, the operators invariably raised it on timbers, as they found the brake mechanism more accessible when the machine was raised.

We had first tried out the principle of the brake synchrometer in a machine with wheel drums directly on the flywheels. Later, in attempting to make a more efficient flywheel or one costing less to build, we designed a larger flywheel and reduced the size of the rotor. The rotors on the earlier machine weighed 2015 lb. each; the flywheels which we use today weigh 585 lb., but are geared up so as to give practically the same energy with a 75-per cent reduction in rotor weight.

Vehicle-stopping distances may be determined by averaging the four wheel-readings or by short-circuiting the solenoid that disengages the rotors from one another. All the rotors then travel the same distance, being locked together after the brakes are applied, and each rotor gives the correct number of feet within which the vehicle stops on the road.

Rotors Have High Coefficient of Traction

We are often asked about the traction between the vehicle tires and the brake-synchrometer rotors. I do not know the coefficient on our brake rotors; but, while we have made road tests with the stops on the brake-pedal so adjusted that the car would skid, it would not skid when tested on the brake synchrometer with the same temperature and the same brake adjustments. Hence, the rotors have a higher coefficient than that of any road surfaces we could find.

I have seen a car with very powerful brakes tested on the synchrometer with the rotors, which weighed 600 lb. each and were 34 in. in diameter, revolving at 300 r.p.m. The fact that the brakes stopped the heavy rotors in 1¾ revolutions indicates that there was ample excess of traction over any coefficient found on our present highways.

The brake synchrometer can also be used to determine brake drag and proves very accurate in such work. The machine is so sensitive and accurate that the effect of a drop of oil or water on the brake surface is easily measured. These machines are run, not only in laboratories with every facility and with well-planned lay-outs, but in open lots and uncovered. No source of power needs to be considered when installing them, as the vehicle being tested furnishes the power.

THE DISCUSSION

Question:—How does one know, when a car is on the brake-testing machine, that the brakes are not dragging or overheating before they are applied?

C. F. Smith:—In our case, we run a coasting device. Each car has a normal coasting distance. All the cars have their peculiar characteristics relating to the rear-axle drag. The brake synchrometer measures the retarding effect of the driving gears. You can accelerate to any speed you wish, and are then guided by the coasting effect. If a car fails to coast 400 or 500 ft., you assume that something is wrong and look for it. Likewise, if you see a marked difference, such as the left front wheel running 500 ft. and the rear wheel 300 ft., the reason for this should be investigated. With all the rotors running at the same speed and all subjected to their individual retarding effect, whether or not the brakes are applied, the degree of brake drag is denoted by the shortening-up of the distance run by each wheel.

F. W. Parks[2]:—With the Cowdrey brake-testing machine, the brake drag is determined by the reading itself. Immediately upon starting the motor, and without applying the brake, a certain indication is shown on the dial. Suppose a service station were to handle only one make of car; the mechanics would soon come to know that a given model has a normal rear-wheel drag of 40 to 52 lb. and a front-wheel drag of 20 to 30 lb.; hence any drag in excess of these figures would attract immediate attention. However, with the external type of brake, we do not recommend doing away with the use of the feeler gage, because it is impossible not to have small areas touching which do not show up on the machine.

A Member:—Will Mr. Smith explain how the coasting test is made? I assume it is made to determine whether the wheels are really running free.

Mr. Smith:—The rotors are all locked together through clutches so that they are driven positively and in unison, the rotors and recording instruments being so connected that all are operated from a single solenoid that disconnects the clutches and starts the instruments. When the operator closes a switch and the car is allowed to roll, individual wheel readings are given. According to the degree of drag, the runs of the wheels are shortened. A variation of 2 or 3 lb. of pressure in a tire makes a marked difference in the coasting distance.

Question:—How are these machines used at the factory, with cars having new brakes? Would not the

[2] Sales manager, Cowdrey Brake Tester Organization, Fitchburg, Mass.

adjustment be altogether different than after a car had been run a few hundred miles?

CHAIRMAN F. E. H. JOHNSON[3]:—At the factory, you are working with new linings which may have high spots and other conditions that differ from those of the lining in a car that has been run. With one of these machines it is possible to make a better brake adjustment than by the usual method of pulling the wheels around by hand. There is a distinct use for a brake-testing machine in the factory as well as in the service field, as the machine gives definite readings of the braking effect on each wheel.

QUESTION:—Have you ever had a tire blow out during a test on the machine?

MR. SMITH:—We have tested cars with some very soft flat tires, but I have no recollection of any blowing out. We can often detect a weak spot in a tire by the action of the tire. It is impossible for the vehicle to be dislodged if a tire does burst.

QUESTION:—Will Mr. Parks explain how a testing machine operating at a constant rate of speed can be used to determine the stopping distance of cars operated at various rates of speed?

MR. PARKS:—When the brakes are applied, the retarding force remains substantially the same through the entire car-stopping process. Admittedly, the rate of speed is diminishing constantly but, insofar as it is possible to measure it during that short interval of time in which the car is brought to a standstill, the retarding force is practically constant. Our theory, therefore, is that the speed at which this retarding force is measured makes no difference; and for this reason we elect to measure it at low speeds, to minimize rises of temperature in the lining and also to enable us to determine the retarding force. We think that the process of brake adjustment can be performed best at a low brake-temperature.

QUESTION:—Should not the car be freed up before the brakes are tested on the machine?

MR. PARKS:—Yes, if you refer to the adjusting of brakes, but not for merely testing them. A brake-testing machine in a service station is of no use unless the brake mechanism has been put in the proper condition for a test.

[3] M.S.A.E.—General service manager, Noyes Buick Co., Boston.

The Rubber and Tire Outlook

CRUDE rubber production falls into fairly distinct periods. These are:

(1) The period of wild-rubber production, mainly in tropical America and certain parts of Africa
(2) The rise in plantation production
(3) The demoralization of plantation production after the war
(4) The plantation situation under the Stevenson plan

A fifth period, now beginning, is a condition of unrestricted production and exports.

The Stevenson plan in itself, while temporarily effective, was an uneconomic solution of the difficulty. As the British did not control all sources of rubber supply, its net result has been mainly to the advantage of the Dutch rubber-grower, who refused to cooperate in any plan for restriction and whose production increased from 20,000 tons in 1922 to about 95,000 tons in 1927. As a result also, the British ratio of the world's total decreased from about 70 per cent to about 40 per cent.

American companies have had to buy 95 per cent of their raw material from foreign sources and have been more or less at the mercy of foreign attempts to control and manipulate the price. As, owing to the nature of the industry, raw materials must be contracted for in relatively large volume and at relatively long range, inventory losses have been both large and common. As a result, American manufacturers have taken several steps to improve their position in the situation. One American tire manufacturer is developing extensive plantations in Africa. Another has acquired a large acreage in the Dutch East Indies. An automobile producer has purchased 3,700,000 acres in the valley of the Amazon to be developed as a major rubber-producing area. Attempts are being made to produce rubber in the southwestern part of the United States from the guayule shrub. Edison is conducting experiments with rubber plants in Florida with encouraging results.

All these plans are indicative of the determination on the part of American manufacturers to break loose from dependence on foreign-controlled supplies. Any material effect, however, is still some distance in the future. The rubber plantations started during the 1925 price rise will not be in production until 1931. A more important development has been the growth in the use of reclaimed rubber, the employment of which has increased from 67,000 tons in 1922 to approximately 200,000 tons last year. As yet, however, the foreign-controlled supply remains the dominant factor in the market.

TIRE INDUSTRY IN GOOD POSITION

As an offset to the disadvantage of fluctuating raw-material prices, the tire industry is fortunate in having a steadier demand for its products and a better annual expansion in demand than most American industries. In every recent year production has been greater than the year preceding.

Replacement demand is far more important to the tire industry than is that for original equipment. This is indicated by the fact that in 1927 the production of tires was greater by more than 6 per cent than in 1926, while the output of new motor-cars fell off 20 per cent. The 1928 aggregate tire-industry capacity of the Country, some part of which is ineffective, is estimated at approximately 80,000,000 tires. This is less than 15 per cent greater than the estimated requirements of 70,000,000 tires this year.

Since 1922 the number of tire producers has decreased from about 230 to about 90, a decline of 60 per cent. Although there are now about 90 manufacturers, more than 50 per cent of all the tires made are turned out by five large companies. The expenditure for tires in 1928 should exceed $800,000,000, a sum greater than the total cost of all the automobiles produced in any single year up to 1916. —J. R. Nutt, president, Union Trust Co., in *Trade Winds*.

Legislation on Automobile Brakes

By E. H. Lockwood[1] *and* H. W. Best[2]

Semi-Annual Meeting Paper

A DISCUSSION of motor-vehicle-brake laws properly should be preceded by a consideration of the factors upon which safety in the use of brakes depends. During the development stages of the automobile, brakes were applied only to the rear wheels. Braking action was secured by separate drums on each wheel, or by a single drum on the propeller-shaft, which transmitted braking torque through the rear axles. Two sets of brakes were used: service brakes for stopping the vehicle, and parking brakes for holding the vehicle in the absence of a driver. The service brake usually was applied by a pedal, with a spring for releasing the brake when pedal pressure was removed. The parking brake usually was applied by hand, with a ratchet and notched segment for holding pressure on the brake-shoes when desired. The mechanisms for applying the two sets of brakes were entirely independent, each having its own levers, links and shoes. The parking brake, while not convenient for service use, was available in emergencies in case the service brake was disabled, and thus contributed to safety.

Beginning about 1924, manufacturers in this Country introduced brakes on the front as well as the rear wheels; and, by 1927, four-wheel brakes had become standard equipment on all new models of passenger-car. Four-wheel brakes have made an important contribution to the safety of automobiles, as the distance required to make a quick stop has been reduced by about one-half and the tendency of the car to skid on sudden application of the brakes has been reduced. The wear of brake-linings has been reduced, because of twice as much rubbing surface on the shoes.

Four-wheel brakes have brought new problems and complexities into mechanisms for applying brakes, because of the increased number of parts and the special conditions relating to front-wheel action. Hydraulic or pneumatic pipe-lines, carrying fluid under pressure, are often used to transmit force to the brake-shoes, having the advantage of equalizing the force at all the brakes. The hydraulic system is suitable for service brakes only, and when used must be accompanied by mechanically operated parking-brakes, making two entirely independent sets of brakes. Hence this type of brake is not involved in the following discussion.

Mechanical operation of four-wheel brakes has been largely used and apparently has served to transmit pedal pressure to the brake-bands quite as well as the closed-pipe system. Parking brakes can be combined with the service brakes in mechanically operated systems, thus avoiding to a considerable extent the duplication of parts in the braking system.

For a background, the authors give a brief outline of the development of brakes in motor-cars.

Existing legislation, said to be suitable for former conditions with two-wheel brakes, is not suited to present conditions.

A new law has been drafted, for adoption in Eastern States and Provinces, which is planned to meet existing conditions by permitting dual operation of one set of brakes in lieu of duplicate braking systems. The text of this proposed law is given.

While approving some features of this law, the authors express fear that its interpretation might substantially reenact the objectionable features of present laws.

Application of brakes to all the wheels was a long step toward safety, but other factors also must be considered. Probably many good braking systems have lost their effectiveness gradually through wear of the brake-linings and the resulting reduced and perhaps unequal force at the drums. This condition might be remedied by a visit to the service station, but such a visit is not made, as a rule, until the driver has noticed a decided loss of brake control. Improved maintenance could be secured by providing the brake mechanism with convenient adjustments by which the effects of wear could be taken up, giving ample and equalized pressure on all brake-shoes. It is hardly too much to say that adjustments for wear and equalization that could be operated easily by the driver would be another long step in the direction of braking safety.

Many brake mechanisms lose their effectiveness under unfavorable weather conditions. In some cases rain will cause the brakes to require considerably greater pedal pressure, thus sometimes contributing to accidents. Snow or ice may cause even greater trouble, in extreme cases leaving the car with inoperative brakes. Gradual rusting of parts from which the lubricant has been washed off is another source of trouble. Injurious effects of weather can be guarded against by proper design of parts, especially by protecting the drums and shoes from exposure to the elements.

Another possible source of brake trouble is the accidental fracturing or separating of some part of the mechanism as a result of faulty construction or design, but such troubles have become practically unknown under present methods of manufacture and inspection.

The purpose of legislation regarding brake equipment is to protect the public by making sure that all vehicles shall be provided with the safest possible brakes. Existing brake-laws have a general similarity, apparently

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[2] M.S.A.E.—Instructor in mechanical engineering, Sheffield Scientific School, Yale University, New Haven, Conn.

being patterned after early enactments formulated during the two-wheel-brake period. The laws specify, in substance, that every automobile shall be equipped with two sets of brakes which shall be completely independent. This provision was complied with by all two-wheel brakes.

With the introduction of four-wheel brakes, conflict of brake laws and brake mechanisms was discovered, in that the two sets of brakes were not, in all cases, separately applied. Thus the anomalous situation has arisen of efficient four-wheel-brake equipment agreeing with the spirit of the law but not with its letter, while the older and less safe two-wheel brakes conformed with the letter of the law but only imperfectly met existing demands for safety. The situation has been met in a broad-minded way by the motor-vehicle administrators, who have registered vehicles with the new brakes provisionally, pending a final decision on the question of violation of the law. An apparent remedy would be the enactment of new laws establishing broadly the principles that make for safety in brakes, giving to manufacturers a free hand in embodying these principles in future vehicles.

Changes to adapt the brake laws to existing types of equipment are now being considered. A definite recommendation has been made by the Eastern Conference of Motor-Vehicle Administrators, representing Eastern States and Provinces, which has formulated for adoption by the member States the following new law:

Proposed Brake-Law

> Every motor-vehicle operated in or upon any public highway in this State shall be equipped with brakes adequate to control the movement of and to stop such vehicle. Every automobile so operated shall be equipped with at least two braking systems, with two separate means of application, each operating on at least two wheels and each of which shall suffice to stop the vehicle within a proper distance. If these two systems are connected in any way, they shall be so constructed that failure of any one part of the operating mechanism shall not leave the automobile without brakes on at least two wheels. One of these systems shall be so constructed that it can be set to hold the vehicle. All such brakes shall be maintained in good working order and shall conform to regulations not inconsistent with this act to be promulgated by the Commissioner of Motor Vehicles. Every motorcycle shall be provided with at least one brake, which may be operated by hand or foot.

The proposed brake-law is of importance as registering the views of a body of experienced officials charged with the responsible duty of supervising the safety features of automobile equipment. This law is reported to have been enacted already by the legislatures of several States, and there is prospect of its early adoption by others. The law contains many admirable features, of which the most important is the proposed *uniformity* in the wording and interpretation of such legislation.

It may be useful to list some of the factors that contribute to safety in the use of automobile brakes, of which the following are the more important:

(1) To provide for stopping in the shortest possible distance without dangerous skidding

(2) To have a suitable set of brakes for holding the vehicle stationary

(3) To build the brake mechanism so that fracture or separation of working parts will be practically impossible

(4) To have convenient means of adjustment so that injurious effects of wear can be removed promptly

(5) To protect parts against impairment of effectiveness by weather

If all these features could be incorporated in the brake mechanism complete safety would result, so far as brakes can provide it. The proposed law prescribes two sets of brakes, each set sufficient to stop the vehicle within a proper distance, and one of which shall be a holding brake; also that the brakes shall be maintained in good order. The law further requires that the operating mechanisms of the two sets of brakes shall be independent, with the obvious intent of keeping one set in reserve for use in case of failure of either set.

What Will Be the Interpretation?

Complete separation of the two braking systems is qualified by the clause that, if the two systems are connected in any way, they shall be so constructed that the failure of any one part of the operating mechanism shall not leave the automobile without brakes on at least two wheels. Such a qualifying clause is difficult of interpretation, and the practical outcome might be the requiring of complete separation of the two braking systems, thus substantially reenacting the objectionable feature of the existing law.

The question at issue may be stated thus: Is it desirable, with four-wheel brakes, under present conditions, to require complete separation of the service and parking brakes?

In spite of its official endorsement by motor-vehicle departments, many competent engineers will assert that such separation, with duplication of parts, will subtract from safety about as much as it will add; hence, the duplication of parts is not justifiable. Critics of this part of the proposed law dislike the implication that the service brakes of automobiles of the present high-speed types will fail to such an extent that recourse must be had to the parking brakes. They also feel that, in case of interconnection of the operating parts of the two sets of brakes, the operation of one set would not necessarily be affected by failure of the other set. It may be maintained that some safeguards are needed against future cheapening of brake equipment, with the resulting lowering of safety standards. To this it may be replied that, in the essential units of the automobile, such as braking and steering parts, such safeguards hardly seem necessary since the self-interest of the manufacturer in maintaining public confidence in his product will operate more powerfully than any law.

Three Parties Most Concerned in Safety

In dealing with the problem of safety in automobile brakes it may be recognized that the solution will depend upon the cooperation of three parties, each of whom must contribute his share. First, the manufacturer's part is to construct cars equipped with brakes adequate to stop the car quickly and safely, with provisions for adjustment and protection that will make it possible to keep the equipment in good operating condition at all times. Under present manufacturing conditions it may be assumed that staffs of competent specialists will be working on the problem of new features

that will add to the safety and effectiveness of brakes, as well as to reduce their cost. Encouraging progress already has been made in the direction of reliability and effectiveness of four-wheel brakes, with further development needed in the direction of better means of adjustment and better protection against weather.

Second, the State motor-vehicle departments have general control of the operation of automobiles on the public highways. The motor-vehicle commissioner is in direct contact with every car owner or driver through the annual issuing of car registrations and drivers' licenses. His part in the brake-safety problem is, by advice, threats or punishment, to make the driver keep his brake equipment in good condition and to operate it in a safe manner. This has been done through various channels, such as educational bulletins, rules for the care and use of brake equipment, and legal enactments regarding brakes. That the motor-vehicle departments have much less contact with the manufacturer is unfortunate, since both are working toward the same goal of safer and better automobiles for use on the highways. Possibly some channel for consideration of problems of common interest might be found between bodies like the Conference of Motor-Vehicle Administrators and the National Automobile Chamber of Commerce.

The third party to the problem of brake safety is the car user in whose hands the equipment is finally placed. It must be admitted that the reputation of the typical user for care of the brake equipment is poor. He probably will allow the brakes to lose much of their effectiveness before seeking help from the service station. This condition would be much improved if a simple method of brake adjustment were devised, capable of giving satisfactory results in the hands of an ordinary driver. Even after such brake equipment is available, it will require years for its general introduction; hence car users must be reminded as persistently as possible of the importance of keeping the brakes in good order. These reminders will come, of course, mostly from the motor-vehicle department, with aid from the press and from local automobile clubs and associations.

THE DISCUSSION

J. F. GRIFFIN[3]:—Much remains to be done in educating drivers to keep their brakes in good condition, which can best be done through the various motor-vehicle departments. Two or three times a year a drive is made in every city and sizable town in New Hampshire to check up on the brake equipment. To be sure, faulty brakes are found during each drive, but the inspectors and motorcycle officers report that there seems to be a general improvement.

G. R. WELLINGTON[4]:—The General Assembly of the State of Rhode Island has passed a brake law conforming, as far as possible, with the resolution adopted at the January meeting of the Eastern Conference of Motor-Vehicle Administrators. The only changes are that exceptions are allowed, at the discretion of the licensing authority, on motor-vehicles not exceeding 25 hp. used for road building, and that slight changes have been made in the second and third sentences, making them read as follows:

> Every motor-vehicle, except as hereinafter provided, so operated shall be equipped with at least two braking systems, with two separate means of application, each operating on at least two wheels or on parts of the mechanism firmly connected with two wheels, and each of which shall suffice to stop the vehicle within a proper distance. If these two systems are connected, combined, or have any part in common, they shall be so constructed that the failure of any part of the operating mechanism shall not leave the vehicle without brakes on at least two wheels.

The provision in regard to vehicles for road building was carried over from our old law, while the addition to the first sentence quoted was made because there was doubt that the language as adopted by the Conference was sufficiently clear in regard to the so-called driveshaft brake.

According to my view, the resolution had a two-fold purpose; first, changing the laws to meet accepted standards of engineering with a uniform regulation in a large group of States, and, second, to set up a standard of safety from which manufacturers may not deviate.

The suggestion for some organization that might consider problems of common interest to bodies such as the Conference and the National Automobile Chamber of Commerce has much merit. I feel that an exchange of viewpoints would result in the solution of many problems, in the interest of the general public, and might avoid some unnecessary restrictive legislation.

J. M. HAYES, JR.[5]:—The proposed brake-law will meet absolutely the views of all who are interested in the subject.

I have long appreciated that the human element could not be relied upon in the adjustment of brakes, as skidding is due entirely to the unequal adjustment of brakes. Cars skid to the left on wet or sleek roads. The new modern brake-testing apparatus, which gives accurate readings for each wheel fitted with a brake, is much more accurate, and I believe that the universal use of this will have a very good effect.

FUNDAMENTALS FOR MAKING LAWS

AUGUST W. KALLMYER[6]:—Our attitude on this whole matter can be drawn from the following:

(1) Brakes are placed on motor-vehicles for the purpose of decelerating or stopping the vehicle. Their value as a safety device lies in their ability as a brake and in the unlikelihood of their failure.

(2) To assure safety in brakes on the highways, it is necessary to have reasonable laws and regulations that are sufficiently definite to establish a standard from which both the enforcing officer and the motorist can readily determine when the law is violated. Such regulations should not be so broad as to make enforcement impossible, nor should they be so strict as to make compliance by the motorist impossible, improbable or difficult.

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[3] Commissioner of Motor Vehicles, Concord, N. H.

[4] Chief clerk, State Board of Public Roads, Motor-Vehicle Department, Providence, R. I.

[5] Commissioner of Motor Vehicles, Richmond, Va.

[6] Representing Charles A. Harnett, Commissioner of Motor Vehicles, Albany, N. Y.

(3) Laws and regulations containing requirements for the motorist should not be made without the prerequisite that the car be equipped with devices capable, under normal conditions and when in good working order, of meeting such laws and regulations. For this reason, it is necessary to establish requirements for the car manufacturer as well as for the motorist.

(4) The motorist, as a rule, does not care to go over his car carefully for defects in the design of its equipment. He is not in a position to do this, or to change such equipment readily if he becomes aware of defects. For this reason, proper design of the equipment from the standpoint of safety must be left to the manufacturer.

(5) The motor-vehicle administrator is not particularly interested in design unless there appears a tendency toward, or an actual use of, a design which is unsafe.

No doubt interconnected brake-systems can be made as safe as independent systems. There is no quarrel with those who advocate the economical use of material. A question arises, however, as to how far such interconnection should go. The limit of interconnection is one set of brakes with two handles or means of application. Obviously, a set of brakes constructed so that the failure of any one part will leave the operator helpless is not a safe set. If, however, brakes are constructed so that the failure of a link in the operating mechanism will still leave the operator with brakes sufficient to control his car, it will meet all safety requirements. The qualifying clause in the proposed brake-law appears to cover such a brake, and it does not seem that this is any more difficult of interpretation than is usually the case with any law.

It is practically impossible to write a law that is not subject to some misinterpretation without going into such detail that progress in design is restricted. This, of course, no motor-vehicle administrator wishes to do. The only object of the administrator is to establish some rule that will place a limit on any tendency toward unsafe construction and will be uniform for all States.

Safety Should Be Paramount

Benjamin G. Eynon[1]:—Any discussion of legislation dealing with automobile brakes should not be based on what some persons insist upon terming "relative safety". There can be no compromise with safety, and, from the viewpoint of the motor-vehicle administrator, the object of any motor-vehicle brake law is to secure upon the highways vehicles with brakes that are safe for the daily traffic, which bids fair, within a short period, to become even more congested than it is.

It is a matter of common knowledge that, before the advent of four-wheel brakes, the common legal method was to require an internal and an external brake on two wheels, one operating from the pedal and the other from the hand lever. These were designated as service and emergency brakes, respectively, and were absolutely independent of each other. It was not until it became necessary, or at least economical, to use a single system that the term "parking brake" was used.

It seems that the authors have discounted to some extent the contribution of the emergency brake to safety. True, it was the mechanism used for holding the vehicle in the absence of a driver, but unquestionably many drivers believed, and undoubtedly still believe, that they had available a *separate, effective* and, what is most important, an *immediate* means of stopping their cars in an emergency.

With the increasing tendency to raise legal speed-limits and in some cases to abolish them entirely, and with the propaganda which is being circulated by many motor-car manufacturers advertising high-speed performance for their products, it certainly behooves the authorities to protect the users of the highways by whatever means seem necessary, even though those means may seem to the manufacturer to be unduly restrictive, or the cost not commensurate with his idea of the value of human lives.

There is no question that, through the design and adjustment of four-wheel braking-systems, it is possible to have a much better distributed application of brakes, and, generally speaking, four-wheel brakes are safer than two-wheel brakes. On the other hand, everyone realizes that there are conditions under which four-wheel brakes, if not properly adjusted or not in good working order, are practically as dangerous as no brakes at all, and, if any part of a single-application system fails and more than two wheels are thereby left without effective brakes, a serious accident-hazard at once presents itself.

Why Not Two Sets of Brakes?

It is, therefore, difficult to see how there can be any considerable criticism of the recommendation of the Eastern Conference of Motor-Vehicle Administrators that, if the two braking-systems are connected in any way, they shall be constructed so that failure of any one part of the operating mechanism shall not leave the automobile without brakes on at least two wheels. Certainly, unless the driver's car virtually falls apart, he has a right to expect an auxiliary protective system to guard against something which not only he, but the motor-car manufacturers themselves, admit is likely to happen; that is, failure of the so-called service brake.

This has been called a qualifying clause in the proposed brake-law, and statements are made that it is difficult of interpretation and that the practical outcome might be the requiring of complete separation of the two braking-systems, thus substantially reenacting the objectionable feature of the existing law.

I do not think that the complete separation of the two braking-systems is particularly objectionable, except perhaps to the manufacturer of the motor-car or the maker of the brake, whose governing thought is often influenced by his desire for simplification and reduction of costs; and, if competent engineers assert that such a separation will subtract from safety as much as it will add, it seems that they are concerned with installing brakes on their particular cars only because custom and competition decree that an automobile should have a brake.

Motor-vehicle administrators often are inclined to think that motor-car manufacturers, in their zeal for high production at low cost and their effort to influence the motoring public by highly-colored advertising and sometimes pernicious propaganda, lose sight of the fact that legislators and administrators may be forced by public opinion to enact and enforce even more restrictive regulations, if the general public once begins to look upon the automobile as an engine of destruction or a death-dealing article.

[1] Registrar of Motor Vehicles, Harrisburg, Pa.

It is admitted by the authors of the paper that some safeguards are needed against future cheapening of brake equipment, with the resulting lowering of safety standards; although they feel that perhaps such safeguards are hardly necessary, in view of the self-interest of the manufacturer in maintaining public confidence in his product. It is far from my thought to deny these altruistic intentions on the part of the automobile manufacturers, but is it not a fact that the manufacturers are only now beginning to find out a few things about brakes largely because of the attitude of the motor-vehicle administrators and some of the regulations which the latter propose to enact?

Lessons from New Testing Devices

It has been exceedingly interesting to study the results obtained from tests of braking mechanisms made by mechanical and other means. Undoubtedly, the fact that some engineers refused to believe all that was told them about brakes and decided to check up on the various assertions, devising highly accurate methods for doing so, has brought many manufacturers to a realization of their own shortcomings. It is therefore no surprise that they seem to view the proposed brake-law as the handwriting on the wall.

This is not to say that encouraging progress has not already been made, and it seems that manufacturers and administrators should, by conference and agreement, suggest new laws that will provide for safety in braking mechanisms, so that, on the one hand, simplicity of construction may not result in inadequacy, and, on the other hand, worthy systems may not be refused registration because of drastic interpretation of existing laws.

The proposed brake-law is similar to the recommendation made by the National Conference on Street and Highway Safety. When the model uniform vehicle-code, later to be recommended to the various States for adoption, was under consideration by that conference, the manufacturing interests were strongly represented on the subcommittee which studied the question of brake provisions; and there is very little difference between the regulation proposed by the Eastern Conference of Motor-Vehicle Administrators and that proposed by the National conference. In fact, the difference practically resolves itself into a question of phraseology.

Is it not to be supposed that the manufacturers and engineers then knew what the conditions were; or did they feel that these recommendations might not be enacted into law and were merely a few high-sounding phrases through which they might obtain the applause of the public for their alleged interest in the safety of the owners and drivers of their cars?

It is too likely to be forgotten that it is no longer the principal duty of a motor-vehicle administrator to license automobiles and their drivers and to collect a certain revenue accruing to his State treasury; his problem has grown to a point where he is looked to as the State's authority on safety in traffic, and his largest problem is the conservation of human life.

Competition in the automobile industry is severe, and it is not to be wondered at that sometimes motor-car manufacturers lose a sense of proportion in the emphasis which they place upon certain features of their products and in the almost total absence of consideration for some other features which, from the point of view of the administrator, are highly important.

The entire burden of the brake safety-problem cannot be laid at the door of any one of the three parties most concerned in safety; namely, the manufacturer, the administrator and the car user. Everyone has his part to play, but the administrator must constitute himself a buffer between the automobile manufacturer on the one side and the car user on the other side, with an eye single to the safety, comfort and convenience of the citizens whom he has sworn to serve. It becomes no longer a question of cost, but one of performance.

Brake Safety an Engineering Problem

G. L. Smith[8]:—More can be done by the designer of the braking system toward assuring safety than by any law on brakes. The maximum braking-effect is controlled by (*a*) the coefficient of friction between the tires and the road and (*b*) the shifting of the weight toward the front during deceleration. To obtain the maximum braking-effect, it is necessary to utilize the whole weight of the car for deceleration. This has not been done in braking systems of current design. For full-power brakes, on a car having the weight equally

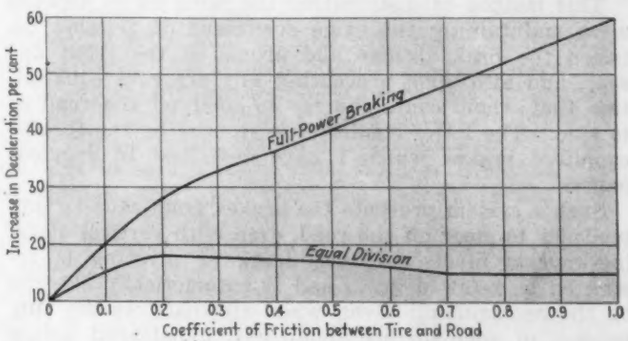


Fig. 1—Relative Deceleration with Various Methods of Distributing Brake-Rod Pull

divided between the axles, the maximum deceleration that can be expected is

$$d = fg \qquad (1)$$

For braking equally divided between the front and the rear axles, the maximum deceleration that can be expected is

$$d = fg/(2fR + 1) \qquad (2)$$

For brakes having 40 per cent of the brake-rod pull on the front and 60 per cent on the rear axle, the braking effect to be expected is

$$d = 5fg/2(5fR + 3) \qquad (3)$$

In these equations, d is the deceleration in feet per minute per minute, f is the coefficient of friction, g is acceleration due to gravity, and R is the ratio of the height of the center of gravity to the wheelbase of the vehicle.

A graphical representation of the increase in braking effect that is available through other arrangements, as compared with the common division of 40 per cent at the front and 60 per cent at the rear axle, is shown in Fig. 1, in which the percentages of gain for an equal division of pull and for full-powered brakes are plotted against the value of the coefficient of friction. The values given are the maximum obtainable without locking a wheel.

[8] M.S.A.E.—Designing engineer, United States Ordnance Co., City of Washington.

Danger from brakes is the result of: (*a*) unbalanced brakes, causing the car to steer off the road; (*b*) badly unbalanced brakes, causing skidding; and (*c*) one or more locked wheels, producing or magnifying (*a*) and (*b*). With an arrangement making possible full-power braking, without locking a wheel, safety would be greatly increased. It is argued that a deceleration greater than 16 ft. per sec. per sec. is too annoying to passengers in a car; but it is better to be annoyed than to be smashed up completely. Aviators can accustom themselves to accelerations 2½ times as great as that due to gravity, which is about three times the maximum theoretical acceleration for an automobile.

Braking Effort Shifted with Weight

It is not difficult to provide for full-power operation of brakes. It involves the use of an inertia weight to vary the distribution of pedal effort between front and rear brakes in proportion to the shifting of weight from the rear axle to the front axle. Such a device is entirely practicable and is not heavy. It will compensate accurately for the shifting of weight due to both deceleration and grade, and will partly compensate for the additional weight of passenger load on the rear axle.

This method of distributing the pedal effort depends upon maintaining the same coefficient of friction between the brake-linings and drums at the front and rear, and also upon preventing any error in equalization that would cause the car to steer off the road or to skid. The latter condition is secured by the torque-equalized brakes which I have described in previous papers[9].

Such a system prevents the brakes from causing any tendency to steer off the road, even with vertical steering-knuckle pivots. Side-skidding or pivoting is restricted to a few degrees and is automotically checked by the mechanism. Even when alternate wheels slip, because of road-surface conditions, unbalanced action is reduced below the danger point, and an error in brake adjustment sufficient to cause the total loss of effectiveness of one non-equalized brake does not reduce the effectiveness of torque-equalized brakes.

The increased complication of four-wheel braking-systems is mentioned in the paper. This complication can be overcome to a great extent by substituting a transmission brake for the rear-wheel brakes, at the same time lightening the rear axle. In the past, transmission brakes have presented several difficult problems; such as rapid wear, overheating, and additional load on the drive. Nevertheless, they have been used with success on some two-wheel-brake cars, and it seems that the difficulties would be eliminated if a transmission brake were used in combination with front-wheel brakes that are worked to the limit of their capacity. To obtain the maximum of safety, why not combine the foot and hand brakes in a system in which pulling back the hand lever one or two notches will have the effect of adjusting the foot brakes when the brake-lining has worn down enough to allow the pedal to strike the floor-boards? This could be accomplished by having the hand brake operate upon the adjustment end of the propeller-shaft brake-band. It might obviate a bad accident in the mountains, and would serve as a warning that the brakes need adjustment.

F. G. Whittington[10]:—I believe that we do not want equalization of brakes; we want compensation. Inertia increases the effectiveness of the brakes of the two outside wheels in making a turn, tending to throw the car off the road. Equalization of the brakes will not change that tendency. With no definite solution in mind, I believe that we should have a compensating effect to correct it.

W. R. Strickland[11]:—A system for compensating the brakes on a turn has been in use, in which the tension on the outer front wheel is released. In some cases the tension on the inner front wheel is increased, but that is not so desirable; it is necessary only to release the tension on the outer front wheel to assure steering in making a turn, even on a wet pavement.

The Manufacturer's Interest in Safety

A Member:—After all, the designer and manufacturer of an automobile that is equipped with brakes of a certain type is more vitally interested in the safety of those brakes than the motor-vehicle administrator possibly can be. If we equip a car with a braking system that is inherently unsafe, we are the ones who will suffer the more.

The proposal of the conference that is causing comment is that no part that is common to the two sets of brakes should be liable to a failure that will make the brakes inoperative. If two entirely separate systems of brakes are to be insisted upon for adequate safety, why not insist also upon two separate steering-mechanisms?

Mr. Strickland:—Safety is the first consideration. Brakes do fail, from one cause or another. I think the most common cause is the gradual wearing of the brake-lining. With four-wheel brakes it is necessary to use increased leverage for easy operation; and that brings us sooner to the point where the pedal can be pressed down to the floor-board, limiting the brake application. A hand lever connected to the same set of brakes will do no good under those conditions.

Engineers must work for safety and make their product as simple as possible, but not merely for the sake of low first-cost. A safe and adequate braking system is a more important problem than safe steering. The steering system may fail, but it is an entirely different kind of mechanism and very seldom does fail.

This is where to apply the advice that we received in one of the sessions yesterday, that the engineer must sell his designs. In our organization I have sold the design for two independent sets of brakes. It was a job, but I sold it, and we have the best possible protection for the customer. Less opposition and more co-operation on the part of engineers will advance our cause further.

Better Wet-Weather Braking Wanted

John Younger[12]:—I agree with Mr. Strickland that the weakest point in the braking system is the brake-lining. After having the brakes in my car relined recently, I found that they were reasonably satisfactory in dry weather but absolutely inoperative during wet weather. A well-known, nationally advertised brake-lining was used, but it is worthless in wet weather. If possible, it should be more effective then, because driving is more hazardous under these conditions; the

[9] See The Journal, February, 1924, p. 111, and June, 1927, p. 754.

[10] M.S.A.E.—Chief engineer, Stewart-Warner Speedometer Co., Chicago.

[11] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

[12] M.S.A.E.—President, editor, *Automotive Abstracts*, Inc., Columbus, Ohio.

driver cannot see so well, and pedestrians are crossing the streets with umbrellas that interfere with watching traffic. Something should be done to produce brake-lining that will operate better when wet.

Dissipating Heat a Problem on Hills

M. C. Horine[13]:—Probably because the discussion so far has been concerned principally with passenger-car brakes, the matter of heat has not been mentioned. A brake is nothing but a means of transforming kinetic energy into heat and dissipating it; and the less kinetic energy there is, the less heat is to be dissipated.

With heavier vehicles at high speed, such as trucks and motorcoaches, the heat factor becomes more of a problem than with passenger-cars; and the necessity for two completely independent systems of brakes is far greater, because of the long grades to be descended with a heavy vehicle.

A perfect single braking-system can hold out for only a certain length of time before sufficient heat will be generated to render the brake ineffective. Applying a secondary braking-system to the same drum is not a solution, because it is the drum that becomes hot, not the asbestos lining. The lining is burned by contact with the hot drum. To apply a secondary set of asbestos surfaces to a drum which is already overheated will not avail us very much. For that reason, I believe that the motor-vehicle administrators have done the right thing in holding out for two independent systems of braking, and I believe this segregation should extend even to the drums. That, it seems to me, is the only objection to Mr. Smith's suggestion of a hand brake-lever operating on a transmission brake that is part of the foot-brake system, so as to serve as a take-up for wear and an auxiliary or parking brake at the same time. We have got into the habit of considering a secondary brake as simply a parking brake, but among the hills it is more than a parking brake.

The effect of equalizers on safety has not been sufficiently emphasized in this discussion. The modern trend is away from equalizers of the whiffletree type, because they do not really equalize, and because, in a fully equalized four-wheel-brake system such as we have seen on some cars, the loss of one little cotter-pin may cause complete paralysis of the braking system. Mr. Smith's system of torque equalization is far more scientific.

Professor Lockwood Sums Up

E. H. Lockwood:—Ways to promote safety of brake equipment, either by legislation or by improved mechanisms, are appropriate to this discussion. Mr. Smith has pointed out the value of equalization of braking on opposite sides of the car as a means for reducing skidding, and of distribution of front and rear braking force in proportion to car deceleration as a means of getting the highest possible brake effectiveness at all times. It is of great interest that mechanisms have now been developed by which these desirable features can be applied automatically.

These suggested improvements in the braking mechanism are indications that the equipment is not yet perfect. Doubtless it is true that many four-wheel brakes have been used while in poor adjustment, giving a bad impression of the system as a whole. This feeling is perhaps over-emphasized by Registrar Eynon in saying that "Everyone realizes that there are conditions under which four-wheel brakes, if not properly adjusted, are practically as dangerous as having no brakes at all." Such troubles may be regarded as unavoidable incidents in introducing a new system whose possibilities have been recognized but whose details have not been perfected by all manufacturers.

Mr. Hayes has referred to the value of modern brake-testing apparatus, now available in many cities, for giving accurate readings of the braking force delivered at each wheel. With such devices at hand, there will be little excuse for poorly adjusted four-wheel brakes. Mr. Strickland and Mr. Younger have referred to the gradual loss of effectiveness by wear of brake-linings, and to the sudden loss of effectiveness when brakes are wet. Both of these troubles may be called strictly engineering problems, whose solution can be made by the manufacturer as soon as their importance has been realized. Such complaints will be more rare as time goes on, not that brake-linings will cease to wear, but that the applying mechanism will remain operative in spite of wear or the effect of water.

How Best To Assure Safety

The various motor-vehicle administrators have made valuable contributions to this discussion by voicing their opinions. Mr. Eynon states very tersely and truly the object of any motor-vehicle brake law "to secure upon the highways vehicles which have safe brakes." There will be agreement on the definition but not on how best to secure the vehicles with safe brakes. In our opinion, there are two chief factors in securing vehicles with safe brakes:

First, to leave the design and construction of brakes to the manufacturer, with no legislative restriction as to details. This may seem like letting down the bars, but it is simply treating brakes like other parts of the vehicle. It is furthermore a recognition that motor-vehicle manufacture is a changing and developing art in which traditions of the past should not hamper the present. It probably is true that better results will be obtained by putting the responsibility of brake safety squarely up to the manufacturer, unhampered by enactments made years in advance by legislators.

Second, the motor-vehicle administrators should promulgate rules by which all car users will be compelled to keep their brake equipment in good order. How these rules are to be formulated and enforced is a problem which the motor-vehicle departments are well qualified to solve. It probably could be worked out in such a way as not to make too much work for the departments and not to be too costly and troublesome for the car user. It seems reasonable for all applicants for registration to file a certificate showing that the vehicle in question had had its brakes examined within the previous 6 months.

Questions such as those brought out by this discussion might well be considered by the proposed conference of motor-vehicle administrators and manufacturers, with promise of practical progress toward a solution of the problems of safety in braking systems. It is to be hoped that steps for such a conference will be taken; and it seems logical for the motor-vehicle administrators, as guardians of the interests of the public, to initiate the conference, to which the manufacturers undoubtedly would give their cordial cooperation.

[13] M.S.A.E.—Manager, sales promotion department, International Motor Co., New York City.

Supercharged-Engine Performance

Discussion of Opie Chenoweth's Aeronautic Meeting Paper[1]

A METHOD of predicting the power output of a given aircraft engine equipped with a direct gear-driven centrifugal supercharger is outlined. The calculations are based on the fundamental assumptions common to internal-combustion engineering.

Three superchargers of different ratings are considered for the purpose of selecting the one giving the best all-round performance. Considerations of weight, compactness, mechanical reliability, simplicity and general arrangement enter into the selection of the best all-round rating.

The effect of superchargers of various ratings on engine power-output, as well as the effect of various factors on engine performance, is shown by curves.

Tests of a supercharged Curtiss D-12 engine were conducted in the altitude chamber of the Bureau of Standards and the results were compared with the calculated results obtained by the method outlined.

Conclusions reached are that, for all-round performance to a definite altitude, an intermediate supercharger-rating should be selected, and that the performance of engines equipped with direct-driven centrifugal superchargers can be predicted with a fair degree of accuracy by the methods outlined.

CHAIRMAN H. M. CRANE[2]:—Will Mr. Chenoweth show by diagrams the general shape of curves obtained with the Roots-type supercharger and also with the gear-driven turbo type, for purposes of comparison?

OPIE CHENOWETH:—The Roots-type supercharger curve probably would be similar to that indicated in Fig. 1; that is, the output of the engine at ground level with the supercharger would be but slightly less than the unsupercharged-engine power. The reasons for this

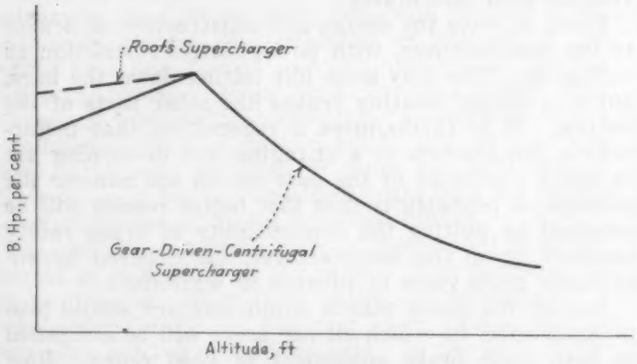


FIG. 1—CURVES OF THE ROOTS-TYPE AND THE GEAR-DRIVEN CENTRIFUGAL SUPERCHARGER COMPARED

improvement in power over that of the geared centrifugal supercharger are (*a*), that the method of controlling the supercharger is to bypass the excess air and therefore the energy diverted from the crankshaft for driving the supercharger is only that required for compressing the air from the pressure existing at the given altitude to a final pressure of 29.92 in. of mercury; and that (*b*), because of (*a*), the temperature rise at the ground is very small and this results in high output.

At the critical altitude the output of the two types of supercharger would be approximately the same. Beyond the critical altitude the output would be highest for the supercharger having the highest efficiency. It is impossible to state which supercharger has the highest efficiency beyond the critical altitude because an engine has not been tested in the altitude chamber with a Roots-type compressor. Many design features influence these results but, in general, it is believed that they would hold true for well-built compressors having the same altitude-rating.

COMPARISON OF CHARACTERISTICS

E. T. JONES[3]:—This is one of the cases in which we made the calculations first and let the Bureau of Standards test the engine in the altitude chamber to check the accuracy of the computations. On the whole, the check is remarkably close. I am somewhat disappointed to find that the powers developed by the engine in the altitude chamber, especially at the peak, fell somewhat below the calculated values, but those tests have not gone far enough yet so that it is possible to determine from the data exactly the reason for the discrepancy between the test values and the calculated values. When the tests are complete, I think it will be possible to check over the calculations in the light of the tests, find out where this discrepancy arises, and bring the method of calculation uptodate so that a much more accurate prediction can be made by this method for any particular case that one may care to investigate.

A comparison between the type of curve that would develop by the use of the Roots-type supercharger and the turbo supercharger, made by superimposing the three curves, would depend, primarily, on the assumptions made as regards the compressor efficiency of the different types of supercharger used. I feel that we are not on as safe ground in talking about the efficiency of the other two types as we are about the type known as the gear-driven centrifugal, for several reasons. The gear-driven-centrifugal apparatus is very neat, and the testing of it is very simple. In respect to efficiency, it lines up almost exactly with the General Electric Co. standard line of centrifugal compressors; so really a great deal is known about the efficiency of these jobs.

[1] Published in the November, 1927, issue of THE JOURNAL, p. 508. The author, a Junior Member of the Society, is carbureter development engineer, aircraft powerplants section, materiel division, Air Corps, Wright Field, Dayton, Ohio. An abstract of the paper is printed above for the convenience of readers of the discussion.

[2] M.S.A.E.—Technical assistant to the president, General Motors Corporation, New York City.

[3] M.S.A.E.—Chief powerplant engineer, Wright Aeronautical Corporation, Paterson, N. J.

and I think we are not likely to deceive ourselves. I think we have not deceived ourselves in assuming that 70 per cent adiabatic efficiency is easily obtainable.

In regard to the Roots-type supercharger, I feel that not so much is known about them, the difficulty being largely that the efficiency of the Roots compressor is very rapidly affected by the operating clearance of the rotors, which is from 0.003 to 0.006 in. around the large perimeter of the rotors. It is not easy to determine that accurately and, having determined it accurately in a static condition, it is perhaps not certain that under running conditions those clearances are maintained. Further, in the actual operation of Roots-type superchargers to date, it has been necessary to increase those clearances rather drastically and this means that the work which has been done by the National Advisory Committee for Aeronautics on the efficiency of the supercharger of that type with small clearance cannot be used directly in arriving at a conclusion as to what they are actually doing in service conditions, because the clearances have been changed.

With regard to the turbo supercharger, the determining of the efficiency of that type of apparatus is much more complicated, because we must consider the efficiency of the turbine and the compressor together. Of course, the two efficiencies are multiplied together and, when we begin to multiply efficiencies of that type, small errors multiply rapidly; but we have given much thought to what that curve would be for the two types, and I would be willing to try to reproduce it.

In general, with the Roots-type supercharger, the efficiency will be lower than with the gear-driven centrifugal at rated altitude. This means that the power lost to the supercharger will be high and the temperature rise of the air will be increased. On the other hand, the power input to the supercharger near the ground will be considerably lower. In fact, at sea level, it is practically negligible; so, with that in mind, we recall the various correction curves. With the Roots-type supercharger, I believe we would start with 100 per cent power and would come up approximately to the same peak as that of the centrifugal type, possibly a slightly lower peak due to the lower efficiency. Above that point, I believe the Roots-type machine would show a more rapid falling off in power. In other words, with the Roots type, I believe we get slightly more power near the ground and slightly less power at altitude.

With the turbine job, there should be no change in the engine power at any altitude up to the rating of the supercharger except that due to the increase in temperature of the air; that is, the turbine jobs are normally operated with sea-level pressure in the exhaust manifold and sea-level pressure in the intake manifold. One does not merely decide to operate that way; the design must be good enough to enable one to operate that way. Such designs have been developed; in fact, I saw some tests recently indicating that the compressor could maintain a higher pressure at the carbureter than was maintained in the exhaust manifold. With that, we get a slight gain due to the fact that the induction pressure is higher than the exhaust pressure. Except for the drop due to temperature rise, in my opinion the turbo-supercharger power would be independent of altitude. We would simply have a horizontal line up to the rating; from there on the turbo jobs have shown the ability to be considerably overspeeded, which is impossible with the gear-driven job; hence, the fall-off is less due to the ability to overspeed. I hesitate to try to predict the particular shape of that curve.

CHAIRMAN CRANE:—I am glad that Mr. Jones spoke at length on this question, because it seems to me to be of considerable interest if we are to look toward a commercial use of supercharging. Its military use is essential, beyond doubt; but, commercially, it is obvious that the advantages will be considerably less. It will not be necessary to work over any such wide range of altitudes for any given machine. It may be possible to operate a transcontinental line so that certain planes stay between the 5000 and the 10,000-ft. level on their part of the trip and others below the 5000-ft. level on their part. In locomotive service, the final result has been a highly specialized fitting of each locomotive to its particular work on the particular division of the railroad on which it operates. The standardization is practically nil. Occasionally an attempt is made to standardize boilers and other parts, but it is impossible to standardize the relations of wheel diameters and number of wheels to cylinder diameters.

The automotive industry has been under considerable pressure in the last few years to explain why it does not use supercharging on cars that run mostly at sea level. It seems to me that, if supercharging is possibly useful in a motor-car, it must be useful to a much greater extent in an airplane. Two types of supercharger have been mentioned here. One can be said to be of two different types: the centrifugal type driven direct from the engine, and the type driven by a centrifugal motor run by exhaust pressure.

CENTRIFUGAL-TYPE SUPERCHARGER

DR. SANFORD A. MOSS[4]:—This paper presents in an admirable way the details of computation of the effect of supercharging at altitude. However, in going over these details, the fact must not be lost sight of that the over-all effect of the use of a centrifugal supercharger is to give a very appreciable gain in the performance of engine and airplane at altitude with very little additional complication. This fundamental fact and many of the details which are presented are now generally admitted; but this has not always been true, and the General Electric Co. research laboratory has had an appreciable task in bringing the centrifugal supercharger to the position which it now occupies.

In the early days it was considered ridiculous to suppose that a mere pinwheel, rotating in a casing, could have any appreciable influence on engine performance. Only a few weeks ago I was seriously assured by an aviation engineer that, even though a centrifugal supercharger maintained a given pressure in the intake manifold of an engine, it was not positive, and that a positive-displacement machine, maintaining exactly the same pressure in the intake manifold, would be much more effective in forcing air into the engine. Of course, the fact is that a given manifold pressure will result in a given amount of supercharging, regardless of how the pressure is produced, and Mr. Chenoweth accepts this without question.

Another fallacy which has been prevalent is that the impeller or "fan" of a centrifugal supercharger "fans" the air and produces a serious temperature rise, so that, even though a centrifugal machine had the same efficiency as a positive-displacement machine, the tempera-

[4] Thomson Research Laboratory, General Electric Co., Lynn, Mass.

ture rise would be much greater. Of course Mr. Chenoweth accepts without question the thermodynamic necessity that temperature rise depends only upon efficiency.

The figure of 70 per cent which is used in the paper for the efficiency of a centrifugal supercharger is a good average for a machine under actual conditions of operation on an airplane engine, if properly designed for these conditions. The various blade-shapes and angles and widths, the diffuser proportions and all the details must be carefully arranged. If this is not done, the efficiency may have any lower value whatever. Illicit comparisons have been made between a poorly designed fan and a so-called positive-displacement machine operated at such a low pressure and speed that the efficiency was much higher than would occur in actual operation on an airplane.

The data in the paper are perfectly sound on all of these matters. The foregoing considerations are mentioned only because the word "positive" has been supposed by people who really should know better to have some magical effect in getting air into an engine cylinder which could not be accomplished by a centrifugal supercharger with the same pressure and even better efficiency and, hence, lower temperature-rise.

In making the comparisons about a Roots-type supercharger at sea level, it has been stated by Messrs. Chenoweth and Jones that they thought the power would be virtually zero at sea level. I do not agree with that opinion because a positive-displacement Roots-type supercharger has a considerable task in forcing the air in and out of the lobes and through the openings at the high speed used in an airplane installation, so that a Roots-type supercharger, even though it gave no pressure near sea level, still would consume a considerable amount of power. No data about this have been published; so one guess is as good as another as to whether that power is appreciable or not.

The curves in the paper can be roughly summarized by the statement that, at altitudes of from 12,000 to 16,000 ft., the use of a centrifugal supercharger without an air-cooler practically doubles the power of an airplane engine. This is an important gain, which justifies the use of such a supercharger in most aviation engines. Of course, the work on engine power is an important part of the paper; but it is not all of the matter. As mentioned, the effect of the supercharger on the over-all performance of the plane, with its engine and propeller, must be taken into account. This is equally as great as the effect on the engine performance shown by the curves, and remarkable increases in speed at level flight and in rate of climb have been obtained on planes with supercharged engines.

The paper mentions only the use of a geared supercharger on a water-cooled engine having cylinders in-line. However, remarkable airplane performances have been obtained by the use of geared superchargers on radial engines. Originally, a centrifugal supercharger on a radial engine was used primarily for overcoming carbureter drop and for vaporization. But tests have been made on a number of types of radial engine equipped with centrifugal superchargers at increased speeds so as to give the supercharging discussed in the paper. These tests bear out Mr. Chenoweth's curves. Proper selection of propellers is an important item in this matter.

Mention is made of the difficulty with the supercharger drive in the case of engines having cylinders in-line. No such difficulty has been encountered in the use of superchargers on radial engines, while all the advantages mentioned by Mr. Chenoweth have been secured. Therefore, all the leading manufacturers of radial air-cooled engines now incorporate a centrifugal supercharger as an integral part of the engine. The supercharger is built-in instead of being attached as an independent accessory.

Mr. Chenoweth mentions the advantage of the centrifugal supercharger in the vaporization of the mixture. The great gain in this respect requires a little more than the mention which Mr. Chenoweth gives, however. There is an appreciable improvement in starting characteristics, uniformity of firing, uniformity of distribution, and similar matters when gasoline is passed through a centrifugal supercharger by use of a carbureter located at the supercharger inlet. It is mentioned that a carbureter drop of about 1.5 to 2.0 in. of mercury is common. However, it is believed that the vaporization secured in the centrifugal supercharger will allow the use of lower carbureter velocity and so diminish this drop.

Scavenging Obtainable

Another item of advantage which Mr. Chenoweth does not mention is that, with proper valve-timing, an appreciable amount of scavenging can be obtained; that is, a large portion of the products of combustion occupying the clearance space can be driven out and the clearance space itself filled with fresh charge, due to the difference between the supercharger pressure and the exhaust pressure, if the exhaust and the inlet valves are opened at the proper times. Computations of this effect have been made by others on the assumption that the entire clearance space is exactly filled with fresh charge, instead of with products of combustion as in the unsupercharged engine. This of course gives amounts of power somewhat higher than Mr. Chenoweth's values.

It is to be noted on the curves in the paper that the amounts of power of the supercharged engine at sea lever are somewhat higher in the actual tests than in the computed values and also that at sea level the decrease of speed of the supercharged plane compared with an unsupercharged plane is really comparatively slight in the actual planes. Some of this decrease is probably due to the effect of scavenging a clearance volume which was not taken account of in the paper.

Mr. Chenoweth's computation methods, so far as the centrifugal compressor is concerned, are in conformity with many years of experience of our research laboratory in such matters. His engine data are based on many McCook Field and Bureau of Standards tests; hence his computations of over-all performance should agree, as they do, with tests on the complete apparatus.

A minor matter in the paper seems to require further explanation. He mentions that the latent heat of the vaporization of the gasoline reduces the temperature so that an air-cooler of increased size is necessary. It is to be noted, however, that this reduction of temperature in itself takes the place of a certain amount of air-cooled surface. The centrifugal supercharger vaporizes practically all the gasoline before the cylinder is reached, with the resulting temperature-drop and increase of weight of charge in a given volume. With the unsupercharged engine there is probably some un-

evaporated gasoline at the beginning of the compression stroke. S. W. Sparrow, when at the Bureau of Standards, computed that the vaporization of gasoline gives a 36-deg. fahr. temperature-decrease.

Relation to Engine Power

It is to be noted that a geared centrifugal supercharger operates at full speed all the time, even at low altitudes when very little of the supercharging effect is needed. The test data show that the loss of engine power, due to this, is comparatively small. Flight tests of airplanes, with engines arranged for supercharging to considerable altitudes, show very slight loss of speed at sea level compared with unsupercharged planes. A large part of this slight loss is to be ascribed to the fact that a supercharged plane requires a somewhat larger propeller than an unsupercharged one, so that the engine speed is decreased somewhat.

Proposals have been made to use clutches or bypass valves to unload a centrifugal supercharger, but the loss is so slight that the complication has never been warranted. Of course, the supercharger easily increases the engine power by the amount necessary to balance this loss. The unused supercharging effect at small altitudes also gives a reserve whereby the engine can be made to give more than normal sea-level power as an emergency matter for short intervals. This, of course, requires an engine that can withstand such emergency increase of power without risk.

The paper shows that a supercharger gives somewhat greater increase of power than that which corresponds to the increase in actual weight of charge, because the effect of temperature rise in decreasing weight of charge is partly balanced by some gain due to increased temperature. As a result, the power varies inversely with the square root of the absolute temperature, instead of with the first power, as would occur if the effect of temperature on weight of charge were the only one.

It is to be noted that Mr. Chenoweth's paper covers only supercharging for comparatively small altitudes. For altitudes of 20,000 to 30,000 ft., the exhaust-driven supercharger is now in general use and is giving good satisfaction.

Supercharging at Sea Level

An important item relating to the subject of the paper is the supercharging of aviation engines at sea level. The centrifugal gear-driven supercharger, as Mr. Chenoweth has mentioned, if opened up near sea level so as to give a pressure in the intake manifold greater than standard sea-level pressure, will give a greatly increased amount of power. The engine of course must be arranged to withstand this increase in power. Arrangements for accomplishing this are now in progress and will no doubt be used commercially in the near future. When such an engine is available, centrifugal superchargers will be installed with somewhat higher gear-ratios than are now contemplated. For flying near sea level the supercharger will be partly opened up so as to give whatever increased pressure in the intake manifold the engine can safely take care of. As the plane climbs to higher altitudes the engine power will be maintained at the safe value at sea level by successively opening up the supercharger. Such an arrangement will give all the advantages outlined by Mr. Chenoweth, with still further increase of power at all altitudes, including sea level.

Passenger automobiles in research laboratories, and racing automobiles in all current races, have had remarkable increases of power due to supercharging at sea level, and the same effect is available with the aviation engine. I venture to predict that increased power at sea level, as well as at altitude, in addition to the effect which Mr. Chenoweth discusses, will be secured in all aviation engines in the near future by the use of a built-in centrifugal supercharger.

Reliability Considered

Chairman Crane:—In my occasional contact with aviation I have been impressed with the extreme confidence shown by aviation engineers in computation. I do not blame the early airplane designer for doing all the computing he could, because it was much safer to prove by computation that a plane would not fly than to make a flight test. But, for certain types of work, computation has serious weaknesses due to the fact that it is impossible to predict the stresses produced in a mechanism which is operating at high speed. Computation is a type of test made with pencil and paper, and accurate calculations can be very useful and very effective. A second type of test somewhat similar is a laboratory substitute for an engine test or a flight test, such as the altitude-chamber test made at the Bureau of Standards. Those two types are successful insofar as the man using that form of computation or test is able to imagine with certainty every factor contributing to the actual performance and service, so that each is present in the computation or in the laboratory test. Apparently this particular case was a very good example of how completely all the various items were foreseen in making the original computations.

Reliability in commercial service is bound to be a very important matter. The high speed of the centrifugal type of supercharger makes its reliability very difficult to obtain. I have been informed, by people who ought to know, that racing cars developed to operate in a winning way on one type of track, such as that at Indianapolis, which is a slow-speed track, can be taken to a saucer-shaped board track on which they are capable of higher speed and the engine promptly wrecked by operating them at an average speed of only 2 or 3 m.p.h. more, the supercharger being developed so close to the limit which they are able to withstand that a very small percentage of increase in speed will wreck them.

A supercharger placed between the carbureter and the engine is a very important part of the carbureter, regardless of whether it does any supercharging. The early radial air-cooled engines in this Country had paddles between the carbureter and the engine, but they were no more than sufficient to prevent a drop in pressure; they practically maintained sea-level pressure at the inlet ports at sea level. Even to this extent they were highly important and successful parts of the engine.

I am thoroughly satisfied that an important reason for the success of radial air-cooled engines today is the uniform distribution obtained among the different cylinders. Until that was obtained it was hopeless to expect to run a radial air-cooled engine at really low gasoline-economy. There would always be one or two cylinders which would overheat. It will be extremely

interesting to see how the supercharger works into the commercial field.

Tests Under Supercharging Conditions

H. K. Cummings[5]:—In addition to straight computation on the possibilities of supercharging at different altitudes, the Bureau of Standards has done something the results of which the National Advisory Committee for Aeronautics will publish soon; namely, it has made a determination of ideal supercharging by making tests of this same engine and also of the Liberty engine in the altitude chamber without an actual supercharger but under supercharging conditions. Instead of reducing the pressure at the intake of the carbureter to correspond with each altitude, the air was introduced at atmospheric pressure, thereby giving complete supercharging at all the altitudes of the test.

The improvement which we found in that way was somewhat less than might be anticipated from the computed results. Mr. Chenoweth finds about 1.9 per cent increase in brake horsepower per 1000 ft. up to the rated altitude, and the Bureau of Standards data give about 1.0 per cent increase per 1000 ft. up to 10,000 ft. above sea level.

The Bureau of Standards data presented in Fig. 11 of the paper were preliminary figures with the gallery manifolds mentioned. These manifolds gave very poor distribution, but a material increase in performance was obtained with the same supercharger and the Curtiss manifolds which were subsequently tried. With both sets of manifolds the tests were carried to a 25,000-ft. altitude, and there is a difference of the order of 15 hp. at the rated altitude between those two manifolds. This also results in making the curve come slightly above the computed curve at altitudes above the rated altitude, which perhaps is sufficiently accounted for by the fact that the initial point of the experimental curve is above that of the computed curve.

Supercharger Speed

Dr. Moss:—The reliability of superchargers of the centrifugal type at very high speed depends upon whether they are designed for the high speeds. Reciprocating steam-engines had speeds of 120 r.p.m. for many years and many a flywheel burst at this speed. An impeller for 20,000, 30,000 or even 80,000 r.p.m. can be operated safely if it is designed by people who understand designing. Our company has in operation in various superchargers many high-speed impellers, all of which have been designed to suit the speed at which they are operating, and failures are negligible. The company also has a number of racing-car superchargers in operation and there have been no failures.

Chairman Crane:—Mr. Moss's comments on speeds remind me of the fact that usually, when a forced landing is made by airplane, it is said to be caused by engine failure. The engine may have stopped because there was no gasoline in the carbureter, or for various other reasons, but still it is due to engine failure. It is a responsibility that I feel is a very heavy one to attempt to drive even a very light flywheel which obviously attempts to maintain a highly uniform speed from a powerplant like a gasoline engine. Obviously, there again radial air-cooled engines or radial engines of any kind have, due to the short, stubby single-throw crankshaft, a decided advantage over the longer V-type engine of the 8 and 12-cylinder variety.

O. A. Ross[6]:—No curves showing the air-current turbulence and friction factors of the carbureter, supercharger and manifolds, are observed in the paper. It is suggested that the failure of the actual performance to live up to the computed performance may be due to an acute angular displacement of the curve representing these factors, this angular displacement occurring at an altitude prior to that computed for the maximum ceiling.

Mr. Chenoweth:—In reply to Mr. Ross, the carbureter loss shown by the tables accounts for the air-current friction factor in the carbureter. The frictional loss in the supercharger is cared for by the efficiency figures, and the supercharger is manipulated so that the pressure loss through the manifold is balanced, since a pressure of 29.92 in. of mercury is maintained to the critical altitude of the supercharger. The improvement in performance reported by Mr. Cummings when the standard Curtiss manifolds were used in place of the gallery manifolds reduces the differences between the calculated and the experimental results. This is accounted for by the better distribution of the fuel-air mixture to the various cylinders.

[5] S.M.S.A.E.—Associate physicist, chief of the automotive powerplant section, Bureau of Standards, City of Washington.
[6] M.S.A.E.—Consulting engineer, New York City.

The Vacation for All

Vacation this year will start Saturday afternoon, Aug. 11, and will end Monday morning, Aug. 27. Everyone who has been in the service of the company for 1 year or longer will receive full pay during vacation, one-half to be received before leaving and the remainder upon return. Those who have worked at the shop for more than 3 months will receive 1 day's pay for each month over 3 months' service.

This will be the fourth year for our 2-weeks vacation with pay for the whole plant.

The present vacation plan seems to be well worthwhile. We can recall when the executives and office people had their vacations spread over the entire summer and those in the mechanical departments had no vacation at all; how we were semi-disorganized throughout the entire summer. This has all been eliminated. Besides, everybody gets a 2-weeks rest or change which enables all to come back on the job with renewed zeal and vigor.—From *Kalends*, house organ of the Williams & Wilkins Co.

The Angular Distortion of Crankshafts

In the paper on The Angular Distortion of Crankshafts, by C. A. Norman and K. W. Stinson, printed in The Journal for July, beginning on p. 83, an error was made in reproducing one of the diagrams.

In Fig. 5, the horizontal scale for the root deflection in crank arms is the reciprocal of the cube of the diameter of the adjoining journal, not the diameter of the adjoining bearing.

With this correction, the illustration agrees with formula (3) of the paper.

The Development of Aluminum for Automotive Purposes

By R. S. Archer[1]

Chicago Section Paper — *Illustrated with* Photographs

THE rapid progress of the present age in technical matters is highly gratifying, the author says, but most of us find it something of a problem to keep up with this progress. The automotive industry draws from many highly specialized arts and sciences and there are perhaps few individuals who have time to keep up with the details of progress in all these fields. The last decade has been one of intensive research and development in the aluminum industry. The close relation between this industry and the automotive industry is indicated by the fact that the automotive industry has at times consumed as much as half of the entire aluminum production. It is natural, therefore, that much of the work on aluminum has been done to provide improved products for the automotive industry and some of them are described.

ALUMINUM was first produced in 1825 by a Danish chemist, Oersted. A method for producing it in appreciable quantities by the reduction of aluminum chloride with sodium was worked out by a French chemist, Deville, about 1855. From then until about 1885 the metal was produced commercially in small quantities and found some use, largely for ornamental purposes. The cost of production was high, however, and the price of the metal toward the close of this period was about $10 per lb. The modern aluminum industry began with the work of Charles M. Hall, a student at Oberlin College, Ohio, between 1885 and 1890. This work resulted in the present process for making aluminum, known as the Hall or the Hall-Heroult process, which made possible the subsequent decrease in its cost.

Aluminum is the most abundant of the metals, constituting about 7 per cent of the earth's crust. It is sometimes stated that every clay bank is a potential source of aluminum. This may become true eventually; but at present the principal commercial source of aluminum is bauxite, which is hydrated aluminum-oxide containing oxides of silicon, iron and titanium as the chief impurities. Before any steps are taken to produce metallic aluminum, it is necessary to separate the aluminum oxide from these impurities. The most common method of accomplishing this consists in treating the ore with a solution of caustic soda, which dissolves the aluminum oxide together with some of the impurities. After further operations, a precipitate of pure aluminum-hydroxide is obtained which is calcined to produce anhydrous aluminum-oxide.

Metallic aluminum is produced by the electrolysis of aluminum oxide dissolved in a bath of fused cryolite, that is, sodium aluminum fluoride. The reaction is effected in a reduction pot consisting of a steel shell having a carbon lining which acts as the cathode. Carbon anodes are used and the aluminum is deposited in a molten condition in the bottom of the pot, from which it is tapped at suitable intervals. The production of aluminum thus requires purified aluminum-oxide, cryolite, carbon anodes which are consumed at the rate of roughly 1 lb. per pound of aluminum produced, and electric power which may amount to about 12 kw-hr. per lb. of aluminum. An idea of the importance of electric power in the production of aluminum can be gained from the fact that, at the new aluminum works at Arvida, Que., Canada, an ultimate development of about 1,000,000 hp. is contemplated.

The metal produced as described is the "pure aluminum" of commerce. It contains small amounts of iron, silicon, copper and titanium as impurities. Until recently there was no way of purifying the metal further, but an electrolytic refining process has been developed, largely as the result of efforts of the late William Hoopes, by which metal of very high purity can be obtained. The operation is carried out in a three-layer cell with a molten aluminum-alloy of high specific-gravity at the bottom of an anode and the pure aluminum floating on an intermediate layer of fused fluorides. Metal up to 99.98-per cent purity has been produced and has some interesting properties, including high resistance to tarnishing and corrosion. This metal is very soft, having a Brinell hardness of 15 as compared with 25 for commercial aluminum of about 99.2-per cent purity.

Commercially pure aluminum is used in large quantities for certain purposes, including electrical conductor cable, sheet, foil, aluminum-bronze powder, and molding. For structural purposes, however, greater hardness and strength are required and are obtained by the use of alloys and by heat-treating processes. The important influence of the automotive industry on the heat-treatment of steel is well known. The heat-treating of aluminum is a comparatively new art, and the products made available by this art are just beginning to come into extensive use. After a review of some of the older aluminum-alloys, these modern products will be described.

A distinction can be made between alloys intended for castings and those intended for wrought products. It is well known that mechanical working breaks up the structure of cast alloys and helps to perfect the continuity of the plastic constituent, thus improving the toughness and ductility of the product. There is also a tendency for the various constituents of the alloy, as

[1] Research Bureau, Aluminum Co. of America, Cleveland.

well as any defects which may be present, to be drawn out in the direction of working, thus producing what is known as grain or fiber. It is recognized that the alloy compositions which are most suitable for castings are not in general the most suitable for wrought products.

Aluminum castings can be made by the sand, the permanent-mold, or the die-casting processes. The sand-casting process is the most flexible, permitting castings to be made of largest size and most intricate shape, although thinner sections can be made by the die-casting process. Casting in metal molds offers the metallurgical advantage of chilling the metal, which produces finer structure, greater density and improved physical properties in general. The choice of alloy compositions, however, is somewhat limited by the nature of these processes, and many compositions which can be handled successfully in the sand foundry are unsuitable for permanent-mold or die casting.

There is almost no end to the alloy compositions that have been proposed for aluminum products, both cast and wrought. Only a relatively small number of these, however, stand out as having sufficient value for general commercial use. The compositions and physical properties of the most important of them are given in Tables 1, 2, 3 and 4, and several of these alloys will be discussed in some detail. There are also several alloy compositions that are very useful for certain special purposes, but the limited use of which forbids discussion in the space available.

Aluminum Casting-Alloys

Aluminum-Copper Alloy Containing 8 *Per Cent of Copper.*—In the United States it has been common practice for more than 10 years to employ alloys containing about 8 per cent of copper for what may be termed general-utility purposes. This includes parts which must be produced and machined economically and in which the requirements as to strength and ductility are moderate, such as the majority of crankcases, oil-pans and transmission cases for passenger-cars. The original alloy, containing in addition to 8 per cent of copper only the impurities present in commercial aluminum which have often been limited to a total of 1.7 per cent, has been known as No. 12 alloy and as S.A.E. No. 30.

In commercial practice there have arisen certain variations of this alloy. The original alloy is still preferred for some purposes, particularly in pattern work. In general, however, its casting qualities can be improved by the addition of either iron or silicon beyond the amount ordinarily present as an impurity in 99-per cent aluminum ingot. Two chief variations of the alloy can thus be recognized, in one of which the iron content is kept distinctly higher than the silicon content; in the other, the silicon is kept equal to or somewhat higher than the iron. The first variation is covered by S.A.E. Specification No. 33 and is also known as No. 112 alloy. Specifications for this alloy permit the presence of some zinc, while the copper content can be kept slightly lower than in the original alloy. The second variation, having a higher content of silicon, is known as alloy No. 212. The three commercial varieties of the 8-per-cent-copper alloy possesses substantially the same tensile properties. They differ slightly in machining characteristics, the product covered by S.A.E. Specification No. 33 usually being regarded as the easiest to machine.

Aluminum-Copper Alloy Containing 12 *Per Cent of Copper.*—The ease of obtaining castings free from leaks in aluminum-copper alloys increases with the copper content, which is limited, however, by the increasing brittleness of the product. An alloy containing 12 per cent of copper is used to a considerable extent for castings which must be free from leaks and in which the brittleness is not prohibitive, such as manifolds, carbureter and pump bodies, and the like.

Aluminum-Copper-Iron-Magnesium Alloy, S.A.E. No. 34, *Lynite* 122.—An alloy has been developed especially for use in pistons in which an attempt is made to meet the many and varied requirements of this service to the best advantage. This alloy, which has been used for the great majority of commercial pistons, contains 10.00 per cent of copper, 1.20 per cent of iron, and 0.25 per cent of magnesium. The copper provides good casting-qualities, hardness, and a structure which is resistant to wear. The small addition of magnesium further increases the hardness without increasing the specific gravity, and contributes to the maintenance of strength and hardness at elevated temperatures. The added iron also contributes materially to strength at elevated temperatures, probably improves resistance to wear and, by improving the casting characteristics of the alloy, decreases the chance of unseen defects in the product. The chief use of this alloy is for pistons cast in permanent molds, but it is used also for pistons and other castings cast in sand, such as certain air-cooled cylinder-heads. Its use is indicated where good bearing-qualities and hardness are required, and where its toughness is sufficient.

Aluminum-Zinc-Copper-Iron Alloy.—In Europe, casting-alloys containing about 10 per cent of zinc and 2

TABLE 1—ALUMINUM SAND-CASTING ALLOYS. PROPERTIES OBTAINED FROM INDIVIDUALLY CAST UNMACHINED SAND-CAST TEST-SPECIMENS

Alloy No.	Approximate Composition, Per Cent		Ultimate Tensile Strength, Lb. per Sq. In.	Elongation in 2 In., or Cent	Approximate Yield-Point, Lb. per Sq. In.	Approximate Brinell Hardness No.
100	Aluminum	99.0	12,000 to 14,000	15 to 25	4,000	25
12	Copper	8.0	18,000 to 23,000	1 to 3	10,000	65
112	Copper	7.5	19,000 to 24,000.	1 to 2.5	11,000 (Minimum 60)	65
	Zinc	1.5				
	Iron	1.2				
109	Copper	12.0	20,000 to 28,000	0 to 1.5	15,000	70
43	Silicon	5.0	17,000 to 22,000	3 to 7	7,000	40
45	Silicon	10.0	17,000 to 21,000	1.5 to 3	9,000	50
47[a]	Silicon, (Modified)	13.0	24,000 to 31,000	5 to 15	.....	..
195[a]	Copper 4.0, *HTT* No. 4		28,000 to 38,000	6 to 12	13,500 (Minimum 50)	65
195[a]	Copper 4.0, *HTT* No. 16		30,000 to 40,000	3 to 8	21,000 (Minimum 70)	75
195[a]	Copper 4.0, *HTT* No. 10		36,000 to 50,000	0 to 5	27,000 (Minimum 80)	100
196[a]	Copper *HTT*	5.0	33,000 to 45,000	0 to 2.5	27,000	110
145[a]	Zinc	10.0	25,000 to 37,000	3 to 6	12,000	65
	Copper	2.5				
	Iron	1.2				
122[a]	Copper	10.0	35,000 to 40,000	0 to 1.0	20,000	115
	Iron	1.2				
	Magnesium	0.25				
	HTT 10					
Y or 142	Copper	4.0	30,000 to 40,000	0.5 to 2.0	25,000	100 Minimum
	Nickel	2.0				
	Magnesium	1.5				
	HTT					

[a] The modification process by means of which the properties specified for No. 47 alloy are realized, the production of castings or alloys Nos. 122, 195 and 196 in the heat-treated state, and alloy No. 145, are covered by patents or patent applications owned by Aluminum Co. of America.

per cent of copper have long been popular. Alloys of this type, usually containing somewhat more zinc and copper, were also used extensively in this Country up to about 15 years ago, but were largely abandoned for various reasons, of which perhaps the most important was their hot-shortness. As a result of this quality and of the comparatively inefficient inspection methods of those days, it is probable that many castings were put into service which contained minute casting-cracks. Subsequent failures in service probably were due more to such defects than to any inherent brittleness or aging of the alloys, although it must also be recognized that the control of alloy composition in foundries was rather poor at that time and that the presence of too much zinc would have caused excessive brittleness. Other objections to these alloys were their high specific-

TABLE 2—PERMANENT-MOLD-CAST ALLOYS, STANDARD 0.505-IN. TEST-SPECIMENS

Alloy No.	Approximate Composition, Per Cent		Tensile Strength, Lb. per Sq. In.	Elongation in 2 In., Per Cent	Brinell Hardness No.
43	Silicon	5.0	18,500 to 24,500	3.0 to 8.0	40 to 45
108	Copper	4.5	21,000 to 29,500	1.0 to 4.5	65 to 80
	Silicon	5.5			
45	Silicon	10.0	24,500 to 29,500	4.5 to 10.0	45 to 56
112	Same as sand-cast (as cast)	112	21,000 to 29,000	1.5 to 3.0	70 to 90
122	Copper	10.0	22,000 to 30,000	0.0 to 1.5	85 to 105
	Iron	1.2			
	Magnesium	0.25			
125	Silicon	5.0	17,500 to 22,500	4.3 to 8.0	40 to 45
	Iron	1.0			
	Tin	2.0			
151	Copper	5.5	20,500 to 26,500	3.5 to 7.5	60 to 70
	Iron	1.0			
	Tin	1.0			
152	Copper	10.0	20,500 to 29,500	1.0 to 3.0	85 to 110
195	Copper	5.5	22,000 to 28,000	3.0 to 6.0	60 to 70
	Heat-Treated Alloys				
	Heat-Treatment No.				
195		4	35,000 to 39,000	5.0 to 9.0	70 to 90
195		10	48,000 to 54,500	1.0 to 1.5	110 to 140
122		2	24,000 to 30,000	0.5 to 1.5	90 to 120
122		7	40,000 to 48,000	0.5 to 1.0	125 to 160
122		12	24,500 to 32,500	0.5 to 1.0	125 to 160
122		14	24,000 to 30,500	0.5 to 2.0	95 to 125
122		15	26,000 to 32,500	0.5 to 1.5	115 to 125

gravity, their loss of strength at elevated temperatures, and their comparatively poor resistance to corrosion.

It was discovered by Jeffries and Gibson[2] that both the strength and ductility of alloys of this type can be improved by the addition of iron, and it seems that this addition, when properly controlled, also improves the casting qualities. Such an alloy is now manufactured as No. 145 and offers perhaps the best combination of strength and ductility obtainable in sand castings without heat-treatment. With the improved metallurgical control, foundry practice and inspection methods which are now available, this alloy can be used without fear of the unreliability which was associated many years ago with aluminum alloys of high zinc-content.

Aluminum-Silicon Alloys.—One of the important developments of the last few years has been the use of silicon in aluminum alloys. This element had previously been regarded as an undesirable impurity, but attention was directed to its possibilities by the discovery by A. Pacz[3], about 1920, of a process for refining and improving aluminum-silicon alloys. Aluminum-silicon alloys

[2] U. S. Patent No. 1,352,271, Sept. 7, 1920.

[3] U. S. Patent No. 1,387,900, Aug. 16, 1921.

TABLE 3—NOMINAL COMPOSITIONS OF STRONG WROUGHT ALUMINUM-ALLOYS

Alloy	Copper, Per Cent	Manganese, Per Cent	Magnesium, Per Cent	Silicon, Per Cent
17S and Duralumin	4.0	0.5	0.5	..
25S	4.5	0.8	0.0	0.8
51S	..	..	0.6	1.0
A17S	2.5	..	0.3	..
B17S	3.5	..	0.3	..
C17S	4.0	0.6	0.5	1.25

Note.—Composition specifications include a minimum aluminum-content chosen so as to permit the normal impurities and, in some cases, small additions of other elements for specific purposes. Where not otherwise indicated, iron and silicon are present in amounts usually found in commercial aluminum.

had previously been produced and many of their characteristics had been determined, as, for example, the embrittling effect of excessive iron-content. The work of Pacz came at a time when the aluminum industry was ready to appraise the valuable properties of the alloys and when high-grade silicon could be made at reasonable cost.

Probably the effect of silicon on aluminum alloys that is of most importance, especially to the automotive industry, is the improvement of casting qualities. Silicon reduces hot-shortness and shrinkage and increases fluidity. It is easier to obtain castings that are free from leaks with alloys containing substantial amounts of silicon than with other common aluminum casting-alloys. These valuable properties are obtained in the binary aluminum-silicon alloys whether "modified" or not, and also in complex alloys containing other elements, especially copper, in addition to the silicon.

The process of Pacz consists in treating a molten alloy containing preferably about 13 per cent of silicon with about 3 per cent by weight of a flux containing sodium fluoride and sodium chloride. Without this treatment, sand-cast test-bars of this alloy have a tensile strength around 20,000 lb. per sq. in. with an elongation of about 3 per cent. When the fluxing treatment is properly carried out, the average tensile-strength is about 27,000 lb. per sq. in. and the elongation about 7 per cent. The fracture of the untreated alloy shows a rather coarse, gray, crystalline grain. The treated alloy gives a fine fracture somewhat lighter in color and without the appearance of crystallinity. Examina-

TABLE 4—MECHANICAL PROPERTIES OF STRONG ALUMINUM-ALLOYS

Alloy	Tensile Strength, Lb. per Sq. In.	Yield-Point, Lb. per Sq. In.	Elongation, Percentage in 2 In.	Brinell Hardness, 500-Kg. Load, 10-Mm. Ball	Order in Relation to Increasing Radius for Cold Bends
51SO	14,000 to 19,000	4,000 to 6,000	15 to 30	25 to 32	1
51SW	30,000 to 40,000	15,000 to 20,000	20 to 30	55 to 70	6
51ST	45,000 to 50,000	30,000 to 40,000	10 to 18	90 to 100	12
25SO	23,000 to 35,000	7,000 to 12,000	12 to 20	45 to 55	5
25SW	45,000 to 53,000	15,000 to 30,000	15 to 22	68 to 85	9
25ST	55,000 to 63,000	30,000 to 40,000	16 to 25	90 to 105	11
17SO and annealed duralumin	25,000 to 35,000	7,000 to 10,000	14 to 22	45 to 55	4
17ST and duralumin	55,000 to 63,000	30,000 to 40,000	18 to 25	90 to 105	10
B17SO	20,000 to 25,000		20 to 28	30 to 40	3
B17ST	42,000 to 50,000	20,000 to 25,000	20 to 28	65 to 85	8
A17SO	20,000 to 25,000		20 to 28	30 to 40	2
A17ST	35,000 to 45,000	15,000 to 20,000	20 to 28	55 to 75	7
C17SO	25,000 to 35,000	7,000 to 10,000	12 to 20	42 to 55	4
C17ST	63,000 to 70,000	50,000 to 55,000	8 to 14	95 to 125	13

Note.—Certain modified grades of duralumin are also manufactured. Alloys 51S and 25S are covered by patents owned by Aluminum Co. of America.

tion under the microscope shows striking changes in structure. The alloy is normally hypereutectic, since the aluminum-silicon eutectic occurs at about 11.6 per cent of silicon. The "normal" or untreated alloy accordingly shows small crystals of primary silicon in a matrix of aluminum-silicon eutectic which is fairly coarse. The "modified" or treated alloy shows primary aluminum dendrites instead of primary silicon and the structure of the eutectic is so greatly refined that it can sometimes be resolved only with difficulty under the microscope.

It has been found[4] that the refining action of the Pacz flux is due to the production of metallic sodium by reaction between the flux and the molten aluminum, and that the refining effect can be produced by adding metallic sodium directly instead of using the flux, the amount of sodium used usually being from 0.05 to 0.10 per cent of the weight of the metal treated. The details of the modifying process and the theory of the change in structure have been discussed fully in a paper entitled Modification and Properties of Sand-Cast Aluminum-Silicon Alloys[5], by R. S. Archer and L. W. Kempf.

The most common binary aluminum-silicon alloy used in this Country is one containing 5 per cent of silicon, and it is nearly always used without the modifying treatment. The binary aluminum-silicon alloys are characterized by excellent casting-properties, good ductility, rather low yield-point and endurance limit under fatigue, and machining properties which are not so good as those of some of the common aluminum casting-alloys, such as S.A.E. No. 33.

The modified 13-per-cent-silicon alloy has been used to a considerable extent in Europe for automobile castings. This use has been based on the rather high combination of strength and ductility obtained, and on the lightness of the castings. Silicon is lighter than aluminum, so the aluminum-silicon alloys are slightly lighter than the common casting-alloys containing copper or zinc. This fact, together with the ability to run somewhat thinner sections, makes it possible to save something in the weight of many castings. These considerations have not resulted in as wide a use of this alloy in the United States as in Europe, for various reasons. First, there are available in this Country heat-treated castings which are superior to the modified 13-per-cent-silicon alloy in mechanical properties and also in machinability. These castings, which will be discussed more fully later, were developed in this Country and have not been available in Europe. Second, the demand for thin sections has in many cases been met in this Country by die-castings, the manufacture of which has developed to a higher extent here than in Europe. Finally, the somewhat greater difficulty of machining the aluminum-silicon alloys is regarded as a more serious matter by the large-scale American automobile-producer than by the small-scale European producer.

An alloy containing about 12 per cent of silicon but without any special modifying treatment is used extensively in the manufacture of die-castings in cases in which it permits castings to be made that would be difficult or impossible in the older alloys. The chilling action of casting in dies or permanent molds produces a refining effect[6] analogous to that brought about in sand castings by the addition of sodium.

The normal alloy containing 5 per cent of silicon has attained a considerable use in both sand castings and permanent-mold castings. Many castings for automobile-body construction that were formerly made of a 5-per-cent-copper alloy have since been made of the 5-per-cent-silicon alloy, which casts more easily and has somewhat better ductility, that enables it to be more readily straightened, peened, and the like. It is also more resistant to corrosion.

As already mentioned, the superior casting-qualities of the aluminum-silicon alloys can also be obtained in complex alloys, and a series of such alloys has been developed[7] and put into commercial use. They have greatly extended the possibilities in die-castings and permanent-mold castings. Among the difficult castings of aluminum-copper-silicon alloys which have recently been made in permanent molds may be mentioned covers for overhead-valve engines.

Heat-Treated Castings.—Since the beginning of the aluminum foundry-industry there has been a more or less continuous effort to develop alloys capable of withstanding the most severe types of service. The early efforts were directed mostly toward the attainment of high tensile-strength, and this property was often produced at an undue sacrifice of ductility.

The search for the best product, combining strength and ductility, has led to the development of heat-treated castings of an alloy containing about 4 per cent of copper, known as Lynite 195. See the paper entitled Aluminum Castings of High Strength[8], by R. S. Archer and Zay Jeffries. This alloy as cast in sand contains between the grains a partial network of aluminum-copper eutectic. The constituents of this eutectic are the hard, brittle compound $CuAl_2$ and aluminum containing a small amount of copper in solid solution. By reheating such a casting for a sufficient length of time at a temperature just below the melting point of the eutectic, it is possible to bring substantially all of the $CuAl_2$ into solid solution and this solid solution can be retained by quenching. The casting is then much stronger and more ductile than before the heat-treatment. The solid solution thus obtained is supersaturated, but is fairly stable at ordinary temperatures because of the rigidity of the metal. By reheating the casting to about 300 deg. fahr., however, the supersaturated solution can be caused to break down, with the formation of a very fine precipitate of $CuAl_2$. This results in increased hardness and decreased plasticity.

The heat-treatment at a temperature just below the melting point of the eutectic, which has for its object the dissolving of the greatest possible amount of soluble constituents in the alloy, is referred to as a "solution heat-treatment." The secondary treatment at about 300 deg. fahr. is referred to as a "precipitation heat-treatment", or sometimes as "artificial aging". By varying the temperature and time of the precipitation heat-treatment, it is possible to produce castings having a considerable range of strength and hardness. The properties of some of these products are given in Tables 1 and 2.

Heat-treated castings of this type have now been in commercial production for more than 7 years and have been proved in a wide variety of applications. The first

[4] Edwards, Frary and Churchill, U. S. Patent No. 1,410.461, March 21, 1922.

[5] See *Transactions of the American Institute of Mining and Metallurgical Engineers*, 1926, vol. 73, p. 581.

[6] Archer and Edwards, U. S. Patent No. 1,572,459, Feb. 9, 1926.

[7] Archer, Jeffries and Johnston, U. S. Patents Nos. 1,572,489 and 1,572,490, Feb. 9, 1926.

[8] See *Proceedings of the Institute of Metals Division, American Institute of Mining and Metallurgical Engineers*, 1927, p. 35.

commercial casting was a differential carrier which replaced malleable iron with satisfactory results. Since then there has been a considerable use of heat-treated crankcases for heavy-duty engines, such as those in fire engines, motorcoaches, motor-trucks and aircraft. Other heat-treated castings include cylinder-heads, transmission cases, windshield brackets, door-pillars, brake-shoes, parts for outboard motorboat engines, miscellaneous stressed parts for aircraft, and the like.

Y Alloy.—This alloy, which contains 4.0 per cent of copper, 2.0 per cent of nickel and 1.5 per cent of magnesium, was developed in the National Physical Laboratory in England and was highly recommended for many purposes. Its use has thus far been very limited because it has not appeared to offer advantages sufficient to justify its extra cost. The chief advantage claimed is that of strength at elevated temperatures. Any small superiority which this alloy may possess in this respect over other alloys of lower cost has not generally been considered, even in the case of pistons, to warrant the extra cost, which is due not only to the composition of the alloy but to its melting, casting and working characteristics. Both castings and wrought products of *Y* alloy are subject to improvement by heat-treatment. Heat-treated sand-castings, however, are very brittle, and even chill castings do not possess much ductility as compared with some of the heat-treated castings already mentioned. Some other advantages of *Y* alloy may be brought to light and may result in its more extensive use.

Wrought Aluminum-Alloys

The highest strength and ductility are obtained only in alloys which have been worked mechanically, as by rolling, forging, extrusion, drawing or similar processes, and the physical properties may not be fully developed until the cross-section of the material has been reduced about 90 per cent. The wrought aluminum-alloys can be divided into two classes according to whether or not they can be hardened by heat-treating. Commercially pure aluminum (2S) and an alloy (3S) containing about 1.25 per cent of manganese are hardened in the usual way by cold working and can then be softened by annealing at about 650 deg. fahr. They cannot, however, be hardened by heat-treating. There are now several fairly distinct types of aluminum alloy which can be hardened by heat-treating. The compositions and properties of some of these alloys are given in Tables 3 and 4. Further description is given in the following discussion, and various published articles[9] can be consulted for greater detail.

Aluminum-Copper-Magnesium Alloy.—The development of the modern high-strength aluminum-alloys began with the work of Wilm in Germany about 20 years ago. The term "duralumin" is derived from the name of the firm with which Wilm was connected, the Durener Metallwerke A. G. It has no exact metallurgical meaning but is generally assumed to indicate an aluminum alloy in which the essential additions are copper and magnesium. A typical composition of this type, as given in Table 3, has 4.0 per cent of copper, 0.5 per cent of magnesium and 0.5 per cent of manganese. After hot-rolling and a normal amount of cold-rolling, *H* temper, this alloy in the form of sheet may have a tensile strength around 42,000 lb. per sq. in. with an elongation of 4 per cent. After annealing at 600 to 650 deg. fahr., *O* temper, the tensile strength is about 26,000 lb. per sq. in. and the elongation about 16 per cent. Starting with either the cold-rolled or the annealed material, the alloy may be heat-treated at about 950 deg. fahr. and quenched. Immediately after quenching, the tensile strength is about 45,000 lb. per sq. in. and the elongation about 19 per cent. On standing at ordinary temperatures, or "aging", the quenched alloy undergoes a spontaneous increase in hardness so that, after a few days, the tensile strength is about 60,000 lb. per sq. in., while the elongation is practically unchanged; but the plasticity and workability are decreased.

Probably the earliest conspicuous use of this new material of construction was in the Zeppelins built in Germany during the World War. Use of the material in other fields did not develop commercially as rapidly as might have been expected in view of the attainment of a tensile strength comparable with that of mild steel, combined with the low specific-gravity of aluminum. This was probably due in part to the fact that industry had not yet got the habit which it now has of seeking special materials of construction to meet various needs with the greatest possible efficiency; but it was also due, to an important extent, to the high cost or difficulty of getting the alloy in the desired fabricated forms.

Alloys of the duralumin type containing aluminum, copper and magnesium, are inherently rather difficult to work, just as are certain alloy steels. One of the objectives of metallurgical research in this Country was the production of alloys which could be hardened by heat-treating but which could be more easily worked than the duralumin type of alloy already mentioned. Two distinctly new types of alloy resulted from this work.

Aluminum-Copper-Alloy.—One of these alloys (25S) can be referred to as an aluminum-copper alloy, although it contains, in addition to copper, important additions of silicon and manganese. Its actual composition is given in Table 3. After quenching from about 960 deg. fahr., this alloy does not undergo any appreciable age-hardening at room temperature as does the 17S alloy mentioned. A similar degree of hardening can be produced, however, by a precipitation heat-treatment in the neighborhood of 300 deg. fahr., so that the final tensile-properties of the fully heat-treated material are about the same.

As in the case of the heat-treated castings already described, the high-temperature heat-treatment of the wrought alloys is referred to as a "solution heat-treatment", while the subsequent low-temperature heat-treatment is referred to as a "precipitation treatment" or as "artificial aging". The aluminum-copper alloy (25S) can be used in either of two heat-treated conditions or tempers; (*a*) quenched from a solution heat-treatment and aged only at room temperature, this

[9] Duralumin—A Digest of Information; by H. C. Knerr. Published in the *Transactions of the American Society for Steel Treating*, 1922, vol. 3, p. 13.

New Developments in High-Strength Aluminum-Alloys; by R. S. Archer and Zay Jeffries. Published in the *Transactions of the American Institute of Mining and Metallurgical Engineers*, 1925, vol. 71, p. 828.

Heat-Treatment of Wrought Aluminum-Alloys of High Strength. Published in Data Sheet A1-5601 of the American Society for Steel Treating, September, 1927.

Commercial Forms and Applications of Aluminum and Aluminum Alloys; by P. V. Faragher. See Technical Publication No. 33, Institute of Metals Division, American Institute of Mining and Metallurgical Engineers, September, 1927.

Some Aspects of the Commercial Manipulation of Aluminum; by C. F. Nagel, Jr. See Technical Publication No. 32, Institute of Metals Division, American Institute of Mining and Metallurgical Engineers, September, 1927.

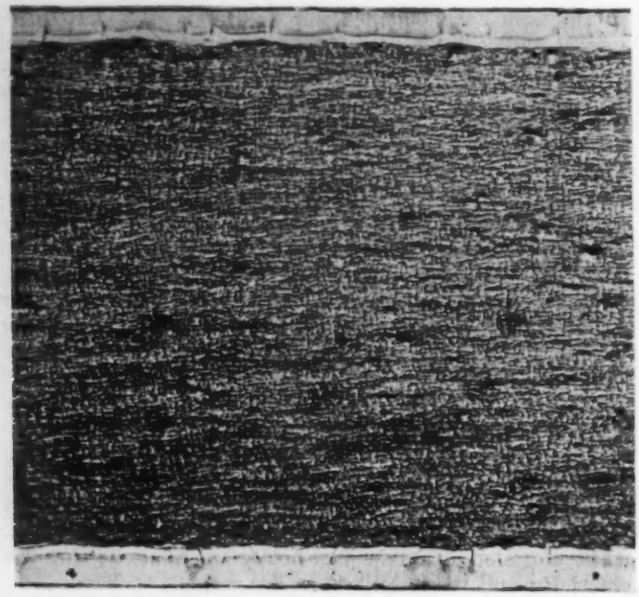


FIG. 1—MICROGRAPH, BY E. H. DIX, JR., SHOWING A CROSS-SECTION OF NO. 14 GAGE ALCLAD 17ST SHEET, MAGNIFIED 50 TIMES

The Section Was Etched with 1-Per Cent Hydrofluoric Acid in Such a Manner That the Diffusion Zone and Grain Boundaries in the High-Purity Metal Are Clearly Revealed, But the 17S Structure Is Severely Over-Etched and Consequently Appears Dark

temper being designated *W*; and (*b*) quenched from a solution heat-treatment and artificially aged to produce increased hardness and strength, this temper being designated *T*. The alloy is generally used in the *T* condition, although the *W* temper has some advantages, including better workability and superior resistance to salt-water corrosion. This alloy can be worked hot, as by rolling or forging, much more easily than the aluminum-copper-magnesium type of alloy. This property has been of great assistance in the development of some of the more difficult fabricated articles such as aircraft propellers, the majority of which are made of this alloy in the *T* condition. The alloy is also used extensively for the manufacture of forged connecting-rods for internal-combustion engines. Its possibilities for parts of larger size are suggested by its successful use in connecting-rods and in the side-rods of railroad locomotives.

Aluminum-Magnesium-Silicon Alloy.—An alloy (51S) having still better working qualities contains magnesium and added silicon, but no copper except that derived from the aluminum ingot as an impurity. The composition is given in Table 3. After solution heat-treating at about 970 deg. fahr. this alloy exhibits spontaneous age-hardening at ordinary temperatures but can be hardened still further to an important extent by artificial aging around 300 deg. fahr. There are thus two tempers, *W* and *T*, as in the case of the aluminum-copper alloy; and the *W* temper is of considerable value because of its great workability. The artificial-aging process can, of course, be applied after material in the *W* condition has been formed by cold-working operations.

Even in the fully heat-treated condition, alloy 51S does not develop as high strength as those previously described. See Table 4. The strength is ample for many purposes, however, and it is to be noted that the yield-point in the *T* condition is as high as, or even higher than, that of the two other alloys. The superior workability of this alloy leads to the economical fabrication of certain forms including tubing, and articles formed from sheet, such as aluminum furniture. It is also the most easily forged of all the strong aluminum-alloys. A rather striking result achieved by virtue of this property is the forging of crankcase halves for a radial aircraft-engine. These forgings would have been very difficult, or commercially impossible, in any of the other strong aluminum-alloys.

Aluminum-Copper-Magnesium-Silicon Alloys. — It will be noted that two of the wrought alloys already mentioned develop a tensile strength of about 60,000 lb. per sq. in. in the fully heat-treated condition. These materials can be further hardened and strengthened by cold working after heat-treating, but the applicability of this means of hardening has evident limitations. There have naturally been attempts to produce alloys of higher strength, obtainable by heat-treating alone, and materials have been made having tensile strengths up to 82,000 lb. per sq. in. The alloys of highest strength contain considerable quantities of zinc and are objectionable from certain considerations including difficulty of fabrication, loss of strength at slightly elevated temperatures, susceptibility to corrosion, and high specific-gravity.

It has been found[16] possible, however, to produce alloys with tensile strengths from 63,000 to as high as 75,000 lb. per sq. in. which are free from zinc. These alloys can be regarded as similar to the aluminum-copper-magnesium type already described, but containing more silicon than is ordinarily found as an impurity in aluminum ingot. The presence of this added silicon makes alloys of this kind susceptible to marked additional hardening by artificial aging. Sheet and certain other forms have been regularly produced in one alloy of this type (C-17S), while another alloy of this type (427S) has been made into forgings on a somewhat experimental basis. Small test-bars cut from forged and heat-treated connecting-rods of the latter alloy have shown strengths from 65,000 to 70,000 lb. per sq. in., with elongations from 19 to 13 per cent, respectively.

Alclad Sheet.—Within the last few years an especially keen interest has been taken in the corrosion of aluminum by salt water. High-strength aluminum-alloy sheet sometimes exhibits corrosion of an intergranular type with consequent embrittlement. This has naturally been a matter of some concern in the construction of aircraft. The corrosive action can be prevented by keeping the material properly protected with suitable coatings such as aluminum-bronze powder in spar varnish or, for surfaces immersed in water, a bituminous paint.

An opportune solution of this problem has been provided by the production of strong alloys on which a coating of aluminum of high purity is rolled in such a way that it is welded to and integral with the base material. Alclad strong-alloy sheet, as it is called, combines the strength of the core with the very high corrosion-resistance of the pure-aluminum coating. See Fig. 1. Furthermore, the pure aluminum has a higher solution-potential than the base material, so that the latter is protected by galvanic action even on cut edges

[16] Jeffries and Archer, U. S. Patent No. 1,472,740; Oct. 30, 1923; filed Dec. 20, 1921.

or at other points where it is exposed. Specimens of this strong-alloy sheet[11] have been exposed to the action of salt spray for one year without any change in tensile properties.

Aluminum Products

The progress made in aluminum alloys and heat-treating would be of limited use without a corresponding progress in fabricating processes. The variety of cast-aluminum and wrought-aluminum products has been greatly extended in respect to both size and complexity of form. At the same time, the costs of the various fabricating operations have been substantially reduced.

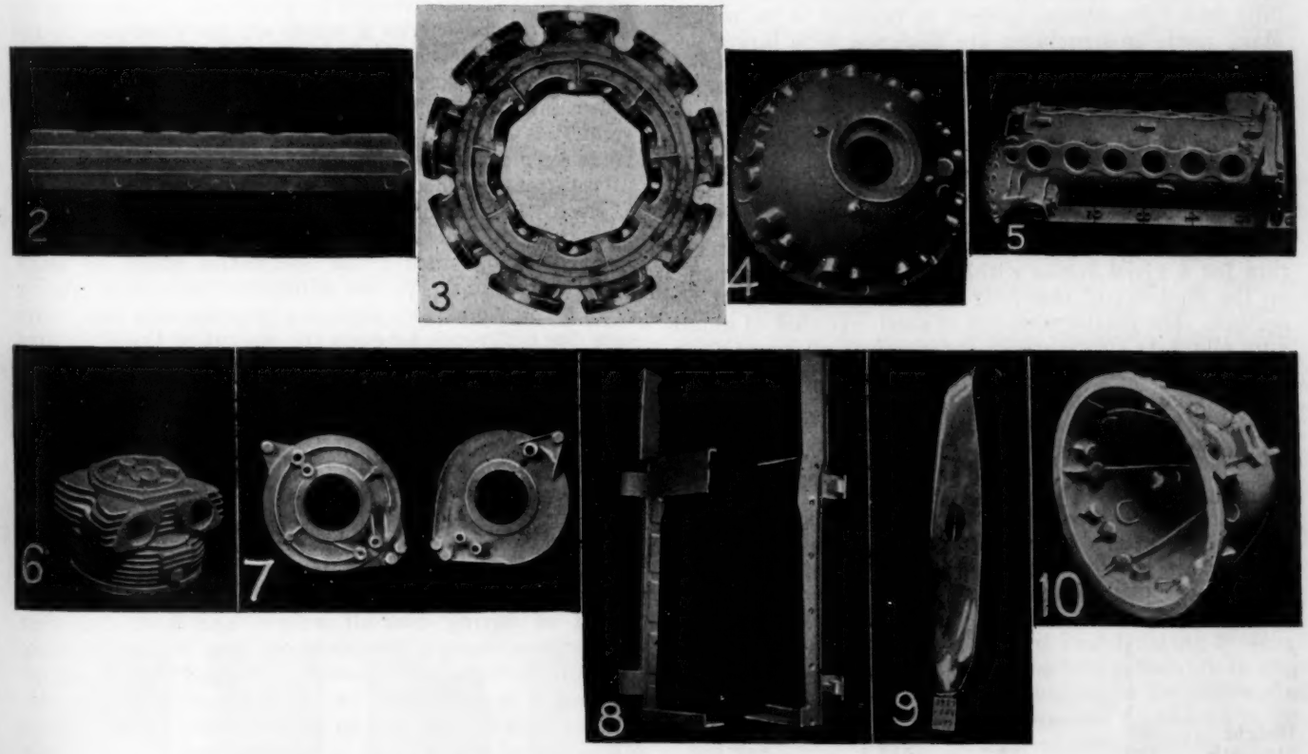
It is beyond the scope of this paper to define the limiting dimensions, tolerances and the like, for various types of product. These factors have been discussed[12] in previous publications and the information is being continuously brought uptodate in the literature of the various producers. In general, it can be said that material in any form required by the automotive industry is now being, or can be, commercially produced. Sand castings weighing up to 3800 lb. have been made; permanent-mold castings up to 57 lb. and die-castings up to 12 lb. have been produced. Larger pieces can be made whenever the requirements arise. Forgings have been made which weigh from about ½ oz. up to 700 lb. Strong-alloy ingots weighing about 2100 lb. and comparable in size with ingots used in steel mills have been successfully rolled on an experimental basis. Aluminum is inherently very adaptable to fabricating processes and no fundamental reason has appeared which seems to impose any limitation on the products that can be made from this metal.

Applications of Aluminum

It is not proposed here to repeat much of what has been said about the application of aluminum to automotive purposes or to give any extended list of specific applications. It may be worthwhile, however, to call attention to a few general principles and to mention a

[11] "Alclad"—A New Corrosion-Resistant Aluminum-Product; by E. H. Dix, Jr.; presented before the annual meeting of the National Advisory Committee for Aeronautics, May, 1927. See National Advisory Committee for Aeronautics Technical Note No. 259, August, 1927.
Corrosion-Resistant Aluminum-Alloys; by E. H. Dix, Jr. See *Mining and Metallurgy*, September, 1927, p. 395.

[12] Some Aspects of the Commercial Manipulation of Aluminum; by C. F. Nagel, Jr. See Technical Publication No. 32, Institute of Metals Division, American Institute of Mining and Metallurgical Engineers, September, 1927.
Commercial Forms and Applications of Aluminum and Aluminum Alloys; by P. V. Faragher. See Technical Publication No. 33, Institute of Metals Division, American Institute of Mining and Metallurgical Engineers, September, 1927.



Examples of Aluminum Parts Now Available for Automotive Purposes

Fig. 2—Cover for the Cylinder-Head of an F-Head Automobile-Engine Made of Aluminum-Silicon-Copper Alloy in a Permanent Mold; Weight 5.22 Lb. Fig. 3—Sand-Cast Crankcase of Heat-Treated 4-Per-Cent-Copper Alloy, Lynite 195-4, for a Radial Diesel Engine; Weight 1200 Lb. Fig. 4—Drop-Forged Nose-Piece for a Radial Aircraft Engine Made of 51S Alloy Heat-Treated to Give a Minimum Tensile-Strength of 40,000 Lb. per Sq. In. and a Minimum Elongation of 12 Per Cent; Weight about 18 Lb. Fig. 5—Sand-Cast Crankcase for a 24-Cylinder Aircraft Engine Made of Heat-Treated 4-Per-Cent-Copper Alloy, Lynite 195-4; Weight 450 Lb. Fig. 6—Sand-Cast Cylinder-Head for an Air-Cooled Aircraft Engine Made of Heat-Treated Y Alloy, Lynite 142-42; Weight 12 Lb. Fig. 7—Automobile Brake-Support Cast in a Permanent Mold; Alloy No. 108, Weight 2.06 Lb. Fig. 8—Automobile Door-Pillars Cast in a Permanent Mold and Made of Heat-Treated 4-Per-Cent-Copper Alloy, Lynite 195-60; Weight 3.83 Lb. Fig. 9—Forged-Aluminum Aircraft Propeller Bent in Service; Illustrative of the Ductility of the Metal. Made of 25S Alloy, Heat-Treated To Give a Tensile Strength of about 60,000 Lb. per Sq. In.; Weight about 40 Lb. Fig. 10—Sand-Cast Nose-Piece of Lynite 195-4 Alloy for a Radial Aircraft Engine; Weight 30 Lb.

TABLE 5—PROPERTIES OF STEEL AND ALUMINUM BEAMS OF CONSTANT WIDTH

	Steel	Aluminum	Aluminum	Aluminum
d	1	1	1.44	2.82
d^2	1	1	2.08	7.98
d^3	1	1	3.00	22.50
Weight	100	35.4	51	100
Strength	100	50.0	104	399
Stiffness	100	33.3	100	750

Assumptions Made

Specific Gravity	7.9	2.8
Young's Modulus, lb. per sq. in.	30,000,000	10,000,000
Tensile Strength, lb. per sq. in.	100,000	50,000

Note.—Comparisons Are Made of the Properties of Steel and Aluminum-Alloy Beams of Fixed Width and Varying Thickness or Depth. These Are the Conditions Encountered in Dealing with Sheet, for Example. The Letter d Represents the Depth of the Beams. It Will Be Noted That for Equal Stiffness the Depth of the Aluminum Beam Is 1.44 Times That of the Steel Beam, Its Weight 51 Per Cent That of the Steel and Its Strength 104 Per Cent. For Beams of Equal Weight the Depth of the Aluminum Is 2.8 Times That of the Steel, Its Strength about Four Times as Great, and Its Stiffness 7.5 Times as Great.

few applications for motor-vehicle and for aircraft use which seem of special interest. (See Figs. 2 to 17.)

Principles of Weight Reduction.—It is not a new principle but is a somewhat neglected one that the possibility of saving weight in mechanical construction by the use of aluminum is often due to its great rigidity under transverse loading in relation to its weight. Many parts or structures are designed with larger sections than would be necessary for the required strength merely to attain the desired stiffness or resistance to deflection within the elastic limit. This is often true where gray-iron castings are used instead of a stronger material such as cast steel, or where plain carbon-steels not heat-treated are used instead of heat-treated alloy-steels.

In simple tension or compression the elastic deformation for a given stress within the elastic limit depends on the modulus of elasticity E and on the area of the section. The elastic modulus of steel, like that of aluminum alloys, is substantially independent of composition, mechanical working or heat-treating within the limits encountered in ordinary practice. A value of 30,000,000 lb. per sq. in. can be taken as representative of the elastic modulus of steel in tension. This is approximately three times the corresponding modulus for aluminum alloys. In tension or compression, therefore, it would be necessary to employ a cross-section of aluminum three times as great as that of steel to attain the same elastic deformation under a given stress. Since the ratio of the specific gravity of steel to that of the average aluminum-alloy is only about 2.8, such a substitution would result in increased weight of material. More often, the problem is one of limiting deflection under transverse or bending stresses as in beams and columns. It is here that the advantage of aluminum becomes marked, since stiffness depends on elastic modulus and on the moment of inertia of the section, which increases rapidly with increasing linear dimensions. Two simple cases will be cited by way of illustration. (See Tables 5 and 6.)

TABLE 6—PROPERTIES OF STEEL AND ALUMINUM BEAMS OF GEOMETRICALLY SIMILAR CROSS-SECTION

	Steel	Aluminum	Aluminum	Aluminum
a	1	1	1.320	1.68
a^2	1	1	1.732	2.82
a^3	1	1	2.280	4.74
a^4	1	35.4	3.000	7.98
Weight	100	50.0	61.4	100
Strength	100	33.3	114.0	237
Stiffness	100	35.3	100.0	265

Assumptions Made

	Steel	Aluminum
Specific Gravity	7.9	2.8
Young's Modulus, lb. per sq. in.	30,000,000	10,000,000
Tensile Strength, lb. per sq. in.	100,000	50,000

Note.—For Simplicity of Comparison, a Square Section Is Assumed. The Letter a Represents the Length of the Side of the Square. For Beams of Equal Stiffness, the Weight of the Aluminum is 61 Per Cent of That of the Steel, and Its Strength 114 Per Cent. For Beams of Equal Weight, the Stiffness of the Aluminum Is 265 Per Cent That of the Steel, and Its Strength 237 Per Cent.

The object of reducing the weight of parts in automobile construction is often more than a desire merely to reduce total weight. In the case of reciprocating parts like pistons and connecting-rods, reduction of weight decreases bearing pressures and inertia whether the reciprocating masses are balanced or not, and, if they are not perfectly balanced, the reduction in weight also results in decreased vibration. The reduction of unsprung weight is regarded as more important than the reduction of weight above the springs because of the attainment of improved riding-qualities. A special object of reducing weight is sometimes to improve the balance of the car as a whole as, for example, in the reduction of weight at the front end. A similar consideration is involved in the use of aluminum bodies to lower the center of gravity of the car. More than the reduction of gross weight is involved in the case of rotating masses, as in wheels where the kinetic energy of rotation is added to that of translation.

Even when the object of reducing the weight of parts is merely to reduce the total weight of the car, it is important to consider the cumulative effect of many small reductions. To use aluminum instead of iron or steel for any one part, such as a transmission case, saves only the difference between the weight of the aluminum part and the iron or steel part. If these savings are sufficiently numerous, however, the aggregate saving may well be such that further reductions become possible in the weight of other parts of the car such as the frame, the springs and, finally, the engine. This cumulative effect becomes most apparent when an attempt is made to use aluminum to the greatest possible extent, as was done in some experimental cars built by our company, to which further reference will be made later.

There is perhaps in some minds a question as to the object of saving over-all weight and a feeling that weight is necessary to obtain the best riding-qualities. In fact, riding-qualities seem to depend chiefly, so far as weight is concerned, on the ratio of sprung to unsprung weight, and also to an important extent on the wheelbase of the car. It is believed that it can be said with fair accuracy that the riding-qualities of a heavy car can be equalled in a light car having the same wheelbase, provided the ratio of unsprung weight to total weight is kept as low. The problem can be considered one of providing a given space in the body for the accommodation of passengers and a given length of wheelbase to produce the desired riding-qualities. The lower the total weight of material used to meet these requirements is, the better will be the acceleration, the hill-climbing ability and the operating economy.

Pistons.—The advantages of aluminum pistons due to their lightness and high thermal-conductivity are now well recognized[13]. Lightness results in reduction of both vibration and bearing pressure. The reduction of vibration is more important the less perfectly the engine is balanced, while the reduction of bearing pressure becomes increasingly important as engine speeds become higher. High thermal-conductivity increases the allowable compression-ratio with less carbon deposited on the piston-head, resulting in less preignition, cleaner and cooler oil and cooler bearings.

The chief obstacle in the use of aluminum pistons has been the high coefficient of thermal expansion, which is about twice that of cast iron. This makes it necessary to fit plain cylindrical aluminum pistons, referred to as trunk-type pistons, with considerably more clearance than is usually allowed for cast iron. This increased clearance may result in what is known as piston slap when the engine is started cold. Many schemes have been devised to compensate for the greater expansion of aluminum compared with cast iron. A few of these schemes have been commercially successful and have played a major part in the rapid growth in the use of aluminum pistons. (See Fig. 11.)

The design which brought the aluminum piston into prominence is the split-skirt design in which the bearing faces are separated from the head by horizontal slots, thus preventing the direct flow of heat from the head to the skirt and thus maintaining a lower skirt-temperature. Up the center of one of the bearing faces runs a vertical slot which allows the wall of the piston to deflect slightly after it reaches the size of the cylinder-bore, thus eliminating the possibility of seizure. The clearance provided with this type of piston is usually about the same as with cast iron.

Recently a demand has developed for still closer clearances, and to meet this demand the insert piston has been developed. This type is similar to the split-skirt type in most of its essential features; but the connection

[13] Light-Alloy Pistons; by G. D. Welty. See *The Journal*, August, 1927, p. 146.

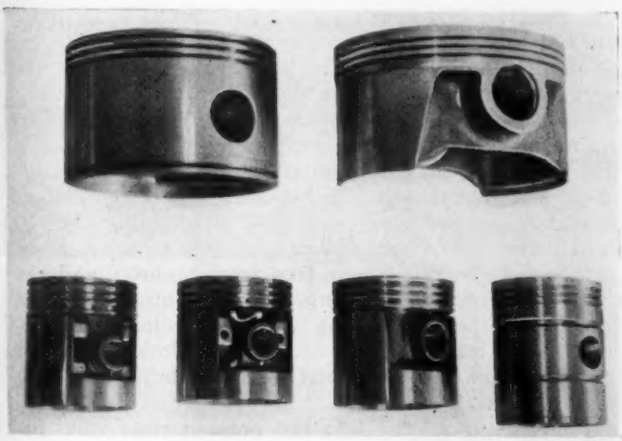


FIG. 11—VARIOUS TYPES OF ALUMINUM-ALLOY PISTON

These Were Made, in a Permanent Mold, of Alloy Containing 10.00 Per Cent of Copper, 0.25 Per Cent of Magnesium and 1.20 Per Cent of Iron. A Trunk-Type Aircraft Piston Is Shown in the Upper Left View, and a Ricardo Slipper-Type Aircraft Piston in the Upper Right View. In the Lower Row, Left to Right, Are Shown Automobile-Engine Pistons of the Following Types: Full-Control Invar-Insert; Single-Strut Invar-Insert; Split-Skirt; and Split-Trunk

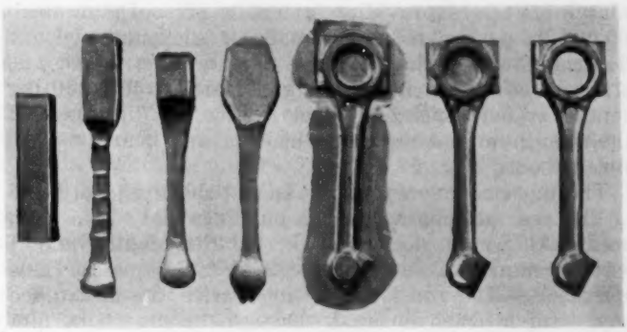


FIG. 12—VARIOUS STEPS IN FORGING AN ALUMINUM CONNECTING-ROD

The Rod Is Made of Alloy 25S and Weighs 1.3 Lb. It Is Heat-Treated after Forging To Give a Tensile Strength of about 60,000 Lb. Per Sq. In.

from the piston-pin bosses to the edges of the bearing faces, instead of being by aluminum ribs, is by steel inserts cast into the piston-pin bosses and into the edges of the bearing faces. These two steel-inserts carry the thrust loads of the piston against the cylinder-wall and act as spacers between the two bearing-faces controlling the expansion across the bearing faces caused by heat. Most of these inserts are made of a steel containing about 33 per cent of nickel, which has a lower coefficient of expansion than ordinary steel. Pistons of this type can be fitted with less clearance than is ordinarily employed with cast iron. They are somewhat heavier and more costly to produce than the all-aluminum type.

Next to expansion, the chief problem in connection with aluminum pistons has probably been that of wear, which becomes most aggravated in the difficulty known as scuffing. It has now been demonstrated that this ailment is due to failure of lubrication, the worst condition being found in engines using a full pressure system with the oil-pump located high on the engine. When the engine is started cold, pistons and cylinders receive no fresh oil for several minutes. The remedy for this trouble lies in providing means for getting fresh oil to the cylinder-walls as soon as the engine is started, and methods have been developed for accomplishing this purpose. With perfect lubrication, aluminum shows practically no wear against cast iron; but it must be recognized that, with imperfect lubrication, aluminum is more subject to wear than is cast iron. In addition to the improvement of lubrication referred to, there has been an important improvement in the hardness of aluminum pistons.

Most commercial aluminum pistons are now heat-treated. The principal object of heat-treating is usually to increase the hardness to improve resistance to wear on the skirt, resistance to hammering in the piston-ring grooves and the piston-pin bosses, and resistance to taking a permanent set in the case of pistons of the flexible-skirt type. Some years ago pistons having a Brinell hardness as low as 70 were used, while a minimum Brinell hardness of 125 is now commercially obtainable. There may be other objects of heat-treating, such as improvement of toughness or prevention of permanent growth.

Connecting-Rods.—Although cast-aluminum connecting-rods are used successfully in some engines of small size, the rods commonly used where high stresses are encountered are drop-forgings of one of the strong

aluminum-alloys providing a tensile strength of about 60,000 lb. per sq. in. Rods made of such material and designed to provide a liberal margin of strength and stiffness offer a saving in weight of about 40 to 50 per cent over corresponding steel rods. The lightness of the aluminum rod reduces vibration and bearing pressures. (See Fig. 12.)

The most common practice is to babbitt the big end of the rod, although inserted bushings have also been used. Aluminum does not take babbitt readily, and it was necessary to develop a special technique for this operation. The rod is first tinned with the assistance of a scratch brush to break through the superficial film of aluminum oxide. The rod will then take babbitt readily. In these operations it is necessary to control carefully the temperatures employed at the time during which the rod is exposed to these temperatures to prevent undue softening of the heat-treated aluminum-alloy. With proper control, satisfactory results are obtained. The high thermal conductivity of the aluminum then assists very materially in keeping the bearing cool. Aluminum connecting-rods have been used successfully for several years in regular production, in a number of automobile and marine engines both here and abroad. They have also been used successfully on an experimental basis in aircraft engines.

Cylinder-Heads.—In addition to lightness, aluminum cylinder-heads offer the advantage of better cooling and the possibility of using higher compression-ratios. (See Figs. 2, 6 and 13.) Sand-cast aluminum cylinder-heads are standard in air-cooled aircraft-engines. Aluminum heads are also used in water-cooled automobile engines and some other engines. These are usually sand castings, but permanent-mold castings have also been used and forgings have been proposed.

Cylinder-Blocks.—There has been some use of aluminum cylinder-blocks, generally with inserted cast-iron liners. An interesting possibility is offered by an alloy cast-iron containing approximately 20 per cent of nickel and 3 per cent of chromium which is reported to have a coefficient of expansion about half way between that of ordinary cast iron and aluminum and not far below that of certain aluminum alloys. With this construction it would be possible to use a light aluminum-piston of the simple trunk-type with clearances virtually the same as with cast-iron pistons. This iron is also much more resistant to rust than is the ordinary grade of cast iron. (See Fig. 14.)

Crankcases.—Some tendency has been evident in the last few years to use cast-iron crankcases instead of aluminum. In nearly all cases this has been done frankly for the purpose of reducing cost. There has perhaps been some feeling that aluminum is less rigid than cast iron; but rigidity can be secured readily by providing suitable sections and ribs. (See Figs. 3 and 5.) There are at present some indications of a return to aluminum on the part of manufacturers who have been using cast iron.

Brake-Shoes.—There is at least one application in which the high coefficient of thermal expansion of aluminum is an advantage. In internal brakes the heating of the brake-drum tends to cause it to draw away from the brake-shoes. The expansion of aluminum brake-shoes helps to neutralize this effect. Aluminum brake-shoes also have the advantage of lightness, rigidity and ability to dissipate heat. (See Figs. 7, 15 and 16.)

Aluminum Wheels.—Several types of aluminum wheel have been designed which are successful from a technical viewpoint, and attempts have been made to commercialize them. Some such wheels have been used in this Country; and it is reported that considerable numbers have been used abroad, especially on motorcoaches. A forged disc-wheel having the brake-drum integral with it offers attractive possibilities. A wheel of this type will be described later.

Tire Valves.—Automobile tire-valves made of high-strength aluminum-alloy rod are now coming into use on what might be termed an extensive experimental scale. Their lightness is of assistance in producing a balanced wheel, and is also believed by some to decrease the danger of injury to the rubber tube in handling. On account of the lower cost of aluminum per unit volume, there is a possibility of making valves more cheaply of aluminum than of brass.

Bodies.—The use of aluminum sheet in body construction makes possible a substantial saving in weight over that of bodies built of steel sheet. This reduces the total weight of the car and lowers the center of gravity. The saving in weight is especially important in doors, because of the decreased loads on the hinges. (See Fig. 8.)

Much is to be said for bodies built up of aluminum castings. A body of this type is likely to weigh about the same as a corresponding body made of steel sheet. It has much greater rigidity, however, which makes it more quiet and improves the accuracy and permanence of alignment and fitting with respect to doors. Trouble has been experienced occasionally in the past with cast-aluminum bodies because of poor adherence or blistering of paint. It is now generally known that proper adherence of paint on aluminum can be obtained by suitable cleaning and roughening of the aluminum surface. The blistering probably was due in most cases to the trapping of volatile matter, such as water or grease, in the pores of the casting before painting. Some trouble may also have resulted from the use of solder or the inclusion of welding or soldering flux beneath the paint. In spite of these difficulties, the majority of cast-aluminum bodies were satisfactory as regards painting. It is believed that such painting difficulties as those mentioned can be satisfactorily overcome and that the use of aluminum castings in bodies offers perhaps the best type of construction as regards quality.

Hardware.—The appearance and the corrosion resistance of aluminum are responsible for its use in numerous parts such as radiator shells, radiator caps and ornaments, step-plates, hood-latches, door-handles, and clutch and brake-pedals. The best results are obtained with heat-treated wrought products, such as forgings, which are entirely free from pinholes and are harder than the usual casting. It is of interest in this connection to point out that, while the color of aluminum does not match that of nickel, it is almost identical with that of the chromium-plating now coming into such extensive use.

Commercial Vehicles.—At the present time keen interest is being shown in reducing the weight of motor-coaches, street-cars and trucks. The urge lies both in economy of operation and in the legal restrictions of maximum load, which are also based on economy. Much weight can be saved by the use of the high-strength aluminum products in frames and bodies. One interesting application is a shipping container for less-than-carload lots. Recent improvements in the arts of press-

ing, welding and riveting simplify the construction of this sort of equipment.

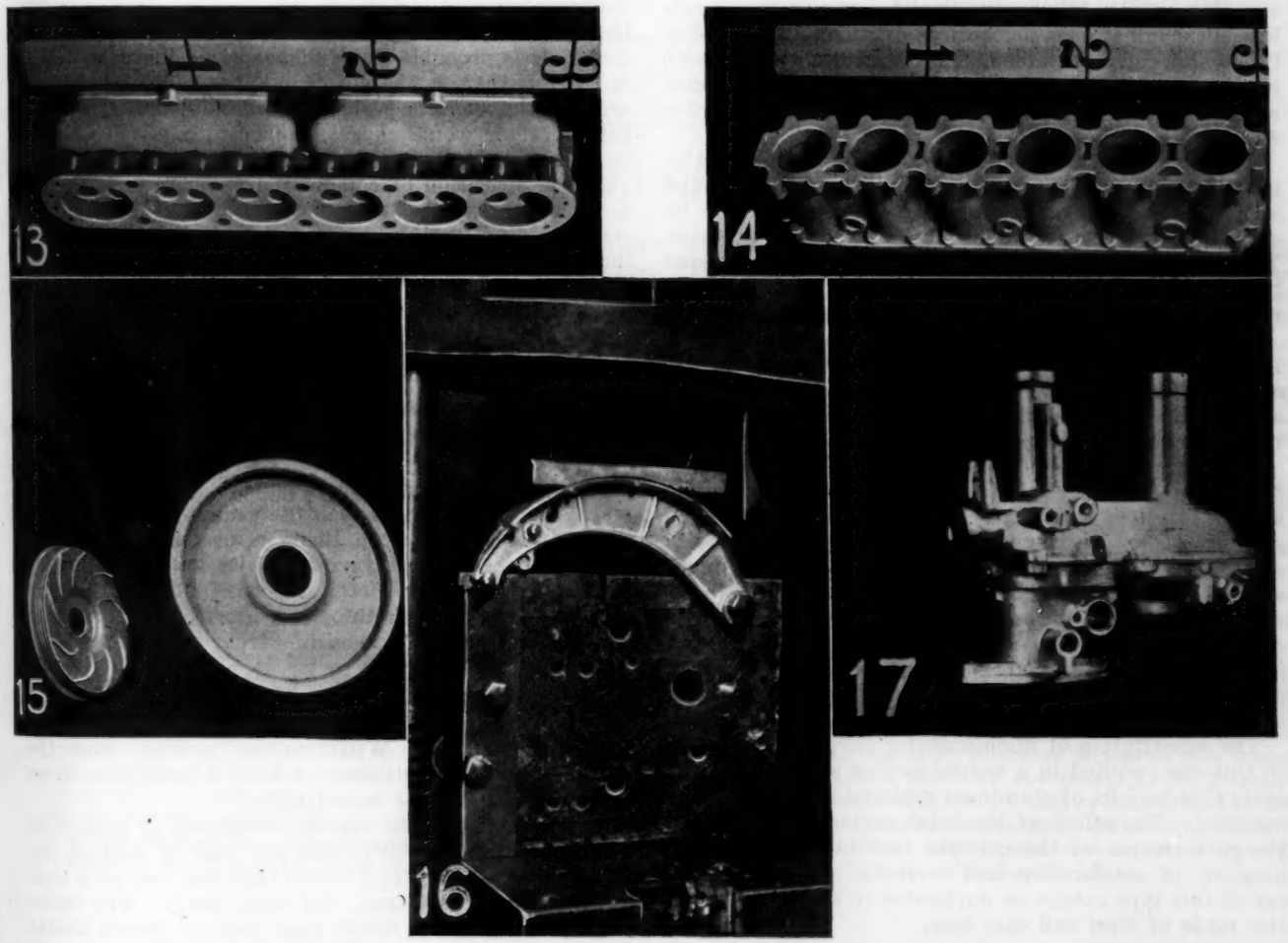
Experimental Aluminum Car

P. B. Jackson has described in detail[14] the results of an interesting and original development in the automobile field. While aluminum, mostly in the form of castings and sheet for bodies, has been used for several purposes almost from the inception of the automobile, a design aiming at the greatest weight-saving possible by the use of aluminum had never been attempted and, indeed, could not have been contemplated without the recent developments in aluminum alloys and fabricating processes. Under the engineering direction of Laurence H. Pomeroy, our company undertook such a development and several cars were built. The construction and the results obtained are described here in a general way.

The chassis, which is of standard tread and has a wheelbase of 133 in., is powered with a six-cylinder L-head engine of 3¼-in. bore and 5-in. stroke and weighs 1800 lb. This represents a weight-saving over a corresponding chassis in iron and steel of about 1000 lb. The body is of cast aluminum and involves no weight-saving over one of similar size and conventional construction. The engine, complete with standard electrical equipment, manifold and carbureter, weighs 452 lb. This is slightly under 6 lb. per hp. as compared with 8 to 10 lb. per hp. in engines using conventional materials. The aluminum parts include crankcase, oil-pan, cylinder-head and cylinder-block, in addition to numerous small parts. The cylinder-block consists of an aluminum casting weighing approximately 40 lb. which incorporates the valve ports and water-jackets, as well as six barrels which are bored out to receive cast-iron cylinder-liners that are shrunk-in.

The front-axle assembly, including a drop-forged aluminum-alloy I-beam section having spring seats and brake-shaft bearings forged integrally, weighs 21 lb. finished, which is slightly less than one-half the weight of corresponding steel parts for cars of this size. The brake support consists of an aluminum casting which also forms a cover over the brake-drum. This casting

[14] An Experimental Development in Light Weight Design, presented by title at the 1927 Semi-Annual Meeting of the Society.



Further Examples of Aluminum Parts for Automobile and Aircraft Use

Fig. 13—Sand-Cast Cylinder-Head of Heat-Treated 4-Per-Cent-Copper Alloy, Lynite 195-4, for an Aircraft Engine; Weight 64 Lb. Fig. 14—Sand-Cast Water-Jacket Made of Heat-Treated 4-Per-Cent-Copper Alloy, Lynite 195.4, for an Aircraft Engine; Weight 42 Lb. Fig. 15—Sand-Cast Brake-Drums of Heat-Treated 4-Per-Cent-Copper Alloy, Lynite 195-4, for Airplane Brakes. The Weights Are 4 and 11 Lb., Respectively, and the Cast-In Steel-Liner Should Be Noted. Fig. 16—Die-Cast Aluminum Brake-Shoe, Made of No. 73 Aluminum-Copper-Silicon Alloy, under a Test for Strength; the Weight of the Casting Being 0.81 Lb. Fig. 17—Die-Cast Aluminum Carbureter-Body of No. 13 Alloy Containing 12 Per Cent of Silicon. This Is a Good Example of a Casting That Is Made in Two Parts, the Weight of Each Part, in This Case, Being 0.51 and 0.62 Lb. Respectively

carries the brake-cam, brake-shoes and pins. The design is exceptionally clean and probably could not be duplicated in any other material without an enormous increase in weight, which would be impractical.

Aluminum castings of rigid design are used for the brake-shoes and, in addition to their lightness, have the advantage of a high coefficient of expansion which neutralizes the expansion of the brake-drum. There is every indication that the temperatures in brakes using aluminum drums and shoes are much lower than in conventional designs. The brake-drum is integral with a disc wheel, drop-forged in 51S alloy. Radial ribs support the brake-drum and make it exceptionally stiff and rigid, eliminating brake squeak. Here, as in many other instances, the thermal conductivity of the material aids greatly in the performance. A cast-iron liner providing a wearing surface for the brake-linings is pressed into place and held by rivets. The brake-liners are unusually narrow. The use of such narrow linings is made possible by the lightness of the car and results in more even distribution of pressure, which lessens the possibility of brake squeak as well as rapid wear and inconsistent functioning of the brakes. It is thus clear that decreased total-weight simplifies the braking problem, although it does not noticeably affect the deceleration which can be attained. The front brake-drum with its liner weighs 27 lb. This replaces in the artillery-wheel assembly a brake-drum, hub, spokes and felloe which weigh about 70 lb.

The rims, of a 21-in. diameter, of the standard 4½-in. Firestone section, are made from extruded aluminum alloy, heat-treated after forming. They weigh 7 lb. each as compared with 18 lb. for a steel rim of this size. The saving is sufficient to make it easy for a woman to place a tire and rim on the tire carrier. The non-rusting property of the rim is also of value.

The front axle, complete with brake-drums, weighs 130 lb. This is unsprung weight and gives the car excellent riding-characteristics. The rear axle employs a large amount of aluminum and, complete with tires, rims, torque-tube and propeller-shaft, weighs 369 lb.

The frame is made of 3/16-in. 51S-alloy sheet pressed in dies for a commercial steel-frame. The spring horns, spring brackets and engine supports are heat-treated aluminum-alloy castings riveted into the frame with steel rivets. The gasoline tank is of welded aluminum-sheet. It has a capacity of 18 gal. and weighs 12 lb. as compared with 30 lb. for a tank of similar capacity and design made of steel. A weight-saving of about 30 per cent is effected in the steering-column by the use of an aluminum outer tube, gearcase and steering-arm. The assembly weighs 29 lb.

The substitution of aluminum for cast iron and steel in this car resulted in a weight-saving of about 50 per cent; that is, 1 lb. of aluminum replaced 2 lb. of another material. The effect of the total saving in weight on the performance of the car was inevitable. The combination of acceleration and economy attainable in a car of this type cannot be duplicated in a car of similar size made of steel and cast iron.

Future of Aluminum in Automotive Industry

In the manufacture of aircraft an extensive use of aluminum alloys appears practically certain. In this field the cost of aluminum, or even of magnesium, is far outweighed by advantages in operation. In passenger-cars, a definite trend toward increased use of aluminum seems to be under way. For several years the chief motive in their manufacture seemed to be reduction of cost, and to attain this end some aluminum was replaced by iron or steel. The automotive industry has itself furnished, however, the great economic lesson that a point can be reached at which further reduction of cost does not produce increased sales. The recent and present emphasis seems to be on performance, although cost is watched very closely. It is perhaps as a result of the present insistence of the public on performance that more aluminum is being used, as in the recently increased use of aluminum pistons. The experimental aluminum-car described has demonstrated very clearly that aluminum construction offers possibilities in the way of performance which are not attainable with steel.

The saving in wieght attained by the use of aluminum results in operating economies due to saving of fuel, tires, and maintenance. This has not been considered very seriously by the average passenger-car user because of the recent low prices for fuel and tires, the comparatively short period of ownership, and the fact that the buyer of a new car usually buys primarily for pleasure and does not pay much attention to operating costs. It is probable that fuel costs will increase and it is possible that, as the automobile becomes more standardized, the average period of ownership may increase. Either factor would cause a buyer to pay more attention to probable costs of operation and maintenance.

In the operation of commercial vehicles such as motorcoaches, taxicabs, and motor-trucks, it seems that very real and important economies can be achieved by the extensive use of aluminum. In the case of the heavier vehicles there is also the consideration of the legal restrictions on maximum load on certain highways. These restrictions are merely another aspect of the principle of economy, since they represent the fact that it is cheaper for the general public to have lighter vehicles than to keep rebuilding roads to withstand heavy vehicles. In the case of vehicles which are operated throughout their entire life by their original purchasers, or which are operated in large fleets, it is justifiable to attach some salvage value to the aluminum used. In brief, therefore, there now seems to be a very real tendency toward increased use of aluminum in automobile construction for the sake of improved performance, and it seems to be only a matter of time until the ultimate economy resulting from such use will be more fully realized.

THE DISCUSSION

Chairman F. G. Whittington[15]:—How does the specific electrical resistance of forged aluminum-alloys compare with that of monel metal?

R. S. Archer:—The specific resistance of aluminum alloys varies from 290 to 220 per cent of that of annealed copper, or 3.8 to 5.0 microhms per cm.^{3} at a temperature of 20 deg. cent. (68 deg. fahr.). The resistance is very much lower than that of monel metal, which has a resistivity of about 45 microhms per cm. at the foregoing temperature.

R. E. Plimpton[16]:—Are there any examples of using aluminum for the structural parts of heavy-duty commercial chassis-frames?

Mr. Archer:—There has been some such use for motorcoaches. The Versare coach is an example.

[15] M.S.A.E.—Chief engineer, Stewart-Warner Speedometer Corporation, Chicago.

[16] M.S.A.E.—Associate editor, *Bus Transportation*, Chicago.

QUESTION:—Is the piece heated when drop-forged, or is it forged cold?

MR. ARCHER:—The forging is done at a temperature of about 800 deg. fahr. After cooling to ordinary temperature the forging is reheated for heat-treatment.

E. W. STEWART[17]:—How does the torsional strength of aluminum compare with that of other metals?

MR. ARCHER:—In general, the torsional strength roughly follows the tensile strength. In one series of tests a cold-drawn steel rod had a tensile strength of 95,000 lb. per sq. in. and a torsional strength of 64,000 lb. per sq. in. A 25S aluminum-alloy rod with a tensile strength of 60,000 lb. per sq. in. had a torsional strength of about 50,000 lb. per sq. in. If the aluminum shaft has a large outside diameter, then the aluminum is stronger and stiffer for its weight, just as is true of beams of similar sections. I believe that a given torsional rigidity or torsional strength can be achieved with less weight if aluminum is used than if steel is used, provided that any outside diameter desired can be employed.

[17] M.S.A.E.—Sales manager, William D. Gibson Co., Chicago.

[18] M.S.A.E.—Research engineer, engine laboratory, Standard Oil Co. of Indiana, Whiting, Ind.

[19] M.S.A.E.—Sales engineer, Aluminum Co. of America, Cleveland.

[20] Fashion Automobile Station, Chicago.

D. P. BARNARD, 4TH[18]:—What would be the procedure for repairing a bent axle or frame made of aluminum?

P. B. JACKSON[19]:—The wreck of a car that had a cast-aluminum frame necessitated new side-members. Within the range of ordinary wrecks that can be repaired, the 51SW-alloy frame-material can be straightened cold without injuring its physical properties.

W. A. MARTINS[20]:—Has a satisfactory process for welding cast, drawn, and forged aluminum been developed?

MR. ARCHER:—Both cast and wrought aluminum-products are successfully welded as a regular thing. It is not practicable to obtain the same strength with the welded as with the unwelded strong-alloy parts. The same is true in general of heat-treated steel parts. Aluminum castings are repaired commercially by welding, and structures such as gasoline tanks are built up of these strong wrought-alloys by welding. In general, however, mechanical joints, such as riveted or bolted joints, are more efficient for strong alloys. Hammered welded joints in 2S and 3S sheet approach the strength of the unwelded sheet.

MR. MARTINS:—In building bodies of sheet aluminum, what process is employed to join the parts?

MR. ARCHER:—Welding is used to join the sheet parts of bodies.

Oil Shale

ALL attempts to produce oil from oil shale fall into one of two groups. They are made either for the purpose of proving a new process or a new retort or combination method for removing the oil from the shale, or they are started with the idea of actually producing large quantities of shale oil to be sold in competition with petroleum.

A certain amount of research and development work along the first line is of great value against the time when our petroleum reserves will have been reduced to a low point, and when the price of petroleum obtained from wells either in this Country or from South America or Asia becomes excessive. In case of an eventual reduction in the supply of domestic crude, a demonstrated, well-understood and economic method for obtaining a substitute oil from our almost inexhaustible supply of oil shale would be of the utmst importance in the time of a National emergency, should our access to foreign sources of crude oil be closed. However, our knowledge on this subject is already extensive from the 75-year-old Scotch oil-shale industry, from the many private experimental installations in this Country, and from the excellent work of both the United States and the Canadian Bureaus of Mines.

However, today we have all the crude oil we require, and new producing areas are being located continually and it seems unlikely that any fundamental change will occur in our petroleum industry in the near future which could make an oil-shale operation economically possible.

There is no oil as such in oil shale; in fact, less than 1 per cent of a waxy material can be extracted with solvents. The oily materials are present as unknown complex compounds which are broken up—cracked—at the temperature of retorting. The extent of this cracking depends on the retorting method employed; and the character of the crude products obtained depends on the method, and also on the particular shale used. Crude shale-oil is generally a highly odorous, black, viscous material, rich in wax and lean in gasoline. This crude oil is suitable charging for present cracking processes and will produce at least 50 per cent of high-grade gasoline with a good antiknock value. The average yield of oil from the shale may be taken as 1 bbl. (42 gal.) per ton, or about one-half barrel of gasoline.

Since crude shale-oil is so waxy and viscous that it cannot be readily transported in pipe lines to distant centers of consumption or to tide water, it would be necessary to finish the cracking and refining near to the location of the shale deposits.

When it is recalled that for every barrel of gasoline produced two tons of rock must be removed from the ground, crushed, screened, dried, retorted, the oil cracked and refined, and the large bulk of spent shale removed, the enormous size of the operation necessary to replace only a small part of the gasoline which we now obtain by the treatment of petroleum from wells can perhaps be conceived. The complexity of the operation is the chief reason why shale oil cannot compete with crude petroleum at $1 or less per barrel.—From Bulletin of Arthur D. Little.

Notes on Valve-Spring Design

By W. T. Donkin[1]

Cleveland Section Paper

A PAPER on Valve-Spring Surge,[2] by Mr. Donkin and H. H. Clark, which was presented at the Semi-Annual Meeting of the Society in May, 1927, was presented during the last season by Mr. Donkin at Section meetings in Buffalo, Chicago and Milwaukee. At a meeting of the Cleveland Section he delivered a paper on Valve-Spring Design, part of which is printed herewith. The remainder was a duplication of the Semi-Annual Meeting paper. At each of these Section meetings the subjects of valve-spring surge and valve-spring design were discussed.

Some of the discussion was upon part of the original paper in which were compared two valve-springs, the original design vibrating noisily and the improved design being satisfactory. The redesigned spring was smaller and the material was subject to higher apparent stress, according to static formulas, but it was less liable to breakage and was subject to lower actual stress because free from the surging that caused more than the calculated static stress in the original spring.

Several of the discussers confirmed points in the paper, and additional information was contributed on multiple and concentric springs and on methods of testing. Discussion at the various Section meetings is included herewith.

DURING the early years of automobile manufacture, valve-springs did not cause much concern So many other problems held the attention of the engineer that he had little time to think of valve-springs. Each year, however, has brought the solution of some problem, and finally valve-spring functions have come under his searching eye. Another factor that has promoted the study of valve-spring action has been the steady increase in engine speed. The early engines were of relatively low speed, but each year has seen an increase of 100 to 200 r.p.m., which has finally brought the speed to a point at which correct operation of the engine depends on a correctly designed spring.

Spring design goes back to the time of Hooke, who, in 1676, expounded the famous law that "in small strains of elastic bodies the stress is proportional to the strain." Since that time other noted scientists have worked on elasticity, notably St. Venant and Love.

Valve-springs, like other springs, obey certain laws and can be designed accordingly. The first item to be considered is the rate of the spring in pounds per inch, in order to find the loads with the valve closed and open. The load in pounds per inch of deflection can be obtained from the formula

$$R_r = Gd^4/8D^3N \qquad (1)$$

where

R_r = rate, in pounds per inch of deflection
G = torsional modulus of elasticity, 12,000,000 lb. per sq. in.
D = mean diameter of spring, in inches
N = number of active coils

After determining the rate, it would be well to check up the stress by the formula

$$S = 8PD/\pi d^3 \qquad (2)$$

where

S = stress, in pounds per inch
P = load, in pounds
D = mean diameter of spring, in inches
d = wire diameter, in inches

Experience has set a value of about 60,000 lb. per sq. in. for the maximum stress and 25,000 lb. per sq. in. as the maximum stress-range. There is a tendency today to treat the stress-range as being unimportant, yet tests and experience tend to show that stress-range is really more important than the maximum stress, up to the elastic limit. Diagnosis of the reason for this shows that, with a high stress-range, the material is put through a large angle of twist which tends to fatigue it quickly and open up any discontinuity in the metal, causing early failure. Therefore, high maximum-stress with a low stress-range is much less destructive, as the material is worked only slightly with each successive compression.

Materials and Heat-Treatments Compared

Material and heat-treatment also must be considered in valve-spring design. It used to be common practice to make valve-springs from oil-tempered spring-wire. With the development of alloy steel the call arose for alloy-steel springs. The spring manufacturer naturally used the same continuous heat-treating process he had used on carbon-steel springs. The expected results were not obtained with the new steel and the old type of heat-treatment. Tests during a 5-year period show that springs made from soft wire, heat-treated after coiling, are far superior to springs coiled from heat-treated wire. Averages of life-tests of springs give the following as the comparative values of springs of different types:

(1)	Carbon steel, heat-treated before winding	1.0
(2)	Electric-furnace chromium-vanadium steel, heat-treated before winding	0.9
(3)	Carbon steel, heat-treated after winding	5.0
(4)	Electric-furnace chromium-vanadium steel, heat-treated after winding	10.0

To those who are looking for the best, we therefore recommend an electric-furnace chromium-vanadium steel that is heat-treated after winding. Where price is a consideration, we believe that the results secured from a carbon steel that is heat-treated after coiling more than offset the slight increase in price due to the method of treatment.

Even though extreme care is taken with the material, heat-treatment and design, failure may sometimes be

[1] A.S.M.E.—Engineer, Cleveland Wire Spring Co., Cleveland.

[2] See The Journal, June, 1927, p. 722, for the paper; and September, 1927, p. 243, for the discussion.

encountered after comparatively short service. Failures of this sort have been traced to the resonance between the natural frequency of the spring and the frequency of the forced vibration from the camshaft. Any force tends to set up a wave motion in the spring, the wave length of which depends upon the natural frequency of the spring. When the forced vibration is of such a frequency that its wave length is a simple multiple of the free wave-length of the spring, a condition of resonance may be created. If the wave length is long and is such that an integral number of the free wave-lengths of the spring are completed during one cycle of the valve, the applications of the force will be in phase, and the resulting wave-motion in the spring will be cumulative and resonant. Ricardo has offered a convenient formula for calculating the natural frequency of a spring. Ricardo's formula is

$$N = 531\sqrt{(R/W)} \qquad (3)$$

where

N = complete number of free vibrations per minute of the spring
R = rate of spring, in pounds per inch
W = weight of the active mass of the spring, in pounds

Because of the slight differences in wire gage and pitch diameter of the springs and the number of active coils, two springs seldom have identical natural frequencies. If the design is good, however, all springs designed for the same frequency will surge within a few vibrations per minute of each other. Hence the formula is valuable for comparison.

If the vibration within the spring is excessive it may cause the valve to float open, and thus impede the operation of the engine and cause excessive hum and noise. In all cases it causes a building-up of stress which is destructive to the life of the spring.

THE DISCUSSION AT CLEVELAND

M. R. WELLS[3]:—During the World War the company with which I was connected had much trouble with valve-spring breakage, almost invariably within the two coils at the end of the spring. To study that, I removed everything except valves, springs and camshaft from the eight-cylinder engine and mounted a pulley on the camshaft. It was possible to see the vibration of the springs, and we tested springs of different designs day and night to determine their life.

To my surprise, we seemed to find that the higher the stress was in a spring, the better results we got from it; and the wider the range of stress, the worse were the results; just as Mr. Donkin reported. Alloy-steel springs of the same design seemed to have shorter life than those of carbon steel.

At that time much of the trouble may have been due to the poor quality of wire available, much of it being seamy stock. One of the spring makers suggested a good test for seamy stock. This was to heat either a spring or a piece of the wire to a bright red and then quench it in oil. This would tend to open wider any seams in the steel. If the wire is broken, in this hard condition, the fracture will follow any seams and show a decidedly cracked surface. A seam is sometimes made clearer if the wire is soaked in gasoline. It is necessary to wrap the wire or take other precautions against flying pieces when it is broken. It is also necessary to quench in oil rather than in water, because water-quenching from such a heat often will start seams in wire that is not already defective.

One point not covered by Mr. Donkin is the twisting that occurs at the lower end of the spring as it is compressed and released. There seems to be some evidence that this twisting action has much to do with the breakage. I believe that Mr. Donkin originated a spring with a decreased pitch in the end coils to overcome the shimmying. Has this design been tested by the method shown by him?

W. T. DONKIN:—We also have noticed a tendency in the spring and the valve to rotate during the critical period; and we believe that this should be of interest to the valve maker, because it causes the valve to seat with a rapid rotating-motion.

The end coils of the spring are given a very great range of stress. In the variable-pitch spring we thought we had a cure-all for valve-spring surge; it limits the stress that can be put on the end coils and in several cases it has worked very nicely, but it is not a cure-all.

MR. WELLS:—A man who was making door checks had trouble with spring breakage. He made a mechanism to operate the spring through its regular operating cycle at a good rate, designed to give a test corresponding to 50 or 60 years of actual service in about 1 day. Springs of a design that proved satisfactory in this test failed in great numbers in service. Can Mr. Donkin explain this?

MR. DONKIN:—If the failures occurred in very cold weather, that might explain the trouble; otherwise, I cannot explain it unless there were defects in the wire.

CHAIRMAN FERDINAND JEHLE[4]:—One of my former professors used to say; "Practice and theory always agree. They cannot disagree, but it is necessary to choose the right theory." It is not in accordance with the laws of the strength of materials that parts worked to higher stress-ranges will last longer than parts less severely worked if made from the same material. We must modify the statement by saying that the parts are worked to a higher *apparent* stress. From Mr. Donkin's pictures there is no doubt that the spring which failed first actually did work through a greater stress-range and at a higher stress. I am sorry that Mr. Donkin did not take a motion picture showing his machine operating at a speed gradually falling from 1500 r.p.m., to show how the vibration periods come and go as the speed drops.

It usually is considered good practice to make the period of spring surge as high as possible. I have tested springs in the laboratory and pronounced them good; and the road-test man would say that they were not good, as he could not use them at a speed beyond 85 m.p.h., or some such useless figure. Perhaps this was a spring that had no bad surge at less than 1800 r.p.m., while a spring that he called better would surge badly at 900 r.p.m. It seems that, if a surge period comes at say 50 r.p.m. below the engine speed corresponding

[3] M.S.A.E.—Research engineer, Cleveland.

[4] M.S.A.E.—Research engineer, White Motor Co., Cleveland.

to the maximum car-speed on a level road, the power of the engine will be reduced so that the maximum speed cannot be attained. If the surge point is at a considerably lower speed, the engine has power enough to drive through it.

Concentric Springs May Help

A MEMBER:—Sometimes I have eliminated trouble by the use of two springs, one inside the other. It is much easier to handle the greater number of small vibration-periods that result from this.

CHAIRMAN JEHLE:—Will the vibrations of two concentric springs neutralize each other?

MR. WELLS:—Not unless the springs touch each other. Each spring has its critical period, the same as a single spring, and I have seen cases in which a single spring performed much better than two springs.

MR. DONKIN:—I agree with Mr. Wells. The critical periods may come at different speeds, but if both springs surge at the same speed the result is very unsatisfactory.

P. F. HACKETHAL[5]:—What about the multiple spring used in aviation engines?

MR. DONKIN:—I have had no experience with that type of spring, but it has been said that if one spring is broken the others will break also.

MR. WELLS:—That may be true in an airplane, but it is not always so. The breaking of the first spring may give warning that will allow the driver to get home at reduced speed. Incidentally, with two springs or with multiple springs, the twisting difficulty can be partly overcome if the spirals are in opposite directions.

ROBERT JARDINE[6]:—The twisting action will be harmful to both the valve and its seat if it becomes excessive, but a slight amount of twisting is beneficial in securing uniform cooling.

MR. DONKIN:—I talked with a man recently who said that valve-seat trouble had been absolutely stopped in certain motorcoaches by redesigning the springs. Some of the old springs were broken every week, and the coaches with the new springs have given more than 5 months of service without a broken valve-spring or trouble with the valve seats.

MR. JARDINE:—When valve-spring surge occurs on a motorcoach within its usual speed-range, the valves get very hot. There is no adequate way of dissipating the heat from a bouncing valve. Sometimes the cylinder-block will show annealing as evidenced by absence of combined carbon at the valve seat to a depth of about 0.01 in. The resulting wear seems to be due both to the twisting action, as shown by gouge marks around the seat with little particles of hard material present in the valve seat, and to washing away the cast iron because of the excessive heat.

THE DISCUSSION AT BUFFALO

CHAIRMAN W. R. GORDON[7]:—In redesigning a valve-spring as described in his paper, Mr. Donkin obviously has increased the stress on the material, since there is less metal to carry the imposed load. What are the heat-treatment and elastic limit of the material used for this spring? The valve-spring is the most highly stressed part of an automobile and is subject to the worst operating conditions. Is there any way to avoid periodic vibration by using a double spring, one damping the other?

MR. DONKIN:—It is true that the apparent stress of the spring has been increased from 41,200 lb. in the old design to 57,000 lb. per sq. in. in the new design; also, the stress-range was increased from 15,000 to 25,000 lb. per sq. in. However, the motion pictures show that at times the adjacent coils of the old spring came into contact with each other, indicating a stress of 69,000 lb. per sq. in. Measurements from the pictures showed an opening that indicates a stress range of 56,000 lb. per sq. in. in the original spring. In reality, the maximum stress was lowered in the redesigned spring by eliminating or reducing the surge. Whereas springs of the original design would break after 1½ hr. of service at 1400 r.p.m., the redesigned spring gave no trouble.

We have tried linking springs, sometimes by placing a retainer between two springs so that they work in series, one partly inside the other. The aim was to make the springs work separately, so that each would counteract the surge periods of the other. We did not get good results from this, but I think the idea has possibilities.

E. W. KIMBALL[8]:—Are not some spring breakages due to dirty dies and other defects entering in the drawing of the wire?

MR. DONKIN:—Without question, surface defects that we formerly thought negligible are important in a highly stressed spring. We now examine a sample from each end of the coil by deep etching with a 50-per cent solution of hydrochloric acid, removing about 0.002 in. of the diameter, and examine it through a microscope that magnifies about 10 times. When we began this investigation we were surprised by the seams, checks and slivers we found. During the last 3 years we have made our requirements for wire as it comes from the mill considerably more exacting. We have procured wire from Germany, Sweden and England, but we find that the American product is better than the European.

GUSTAF CARVELL[9]:—What are the relative merits of straight and conical springs?

Straight Springs Are Preferred

MR. DONKIN:—We have thoroughly investigated straight, conical and barrel-shaped springs. The barrel shape is the opposite of what we recommend, because the center coils are of larger diameter, increasing the mass. The larger diameter makes the spring softer, the rate lower and the frequency lower. The idea of the barrel spring was to avoid concentrated stresses in

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[6] M.S.A.E.—Chief engineer, Rich Tool Co., Detroit.

[7] M.S.A.E.—Sales engineer, Pierce-Arrow Motor Car Co., Buffalo.

[8] M.S.A.E.—Engineer, Vacuum Oil Co., New York City.

[9] M.S.A.E.—Chief draftsman, Curtis Aeroplane & Motor Co., Inc., Buffalo.

the end coil. Conical springs are in the same class. We are working with springs of conventional type only, and find that a spring of small diameter is always to be preferred to one having a large diameter. That is contrary to the old ideas of spring makers, but the small-diameter spring gives less surge.

MR. CARVELLI:—I understand that mud-blasting is better than etching for the examination of wire. The use of hydrochloric acid is too expensive.

We have had trouble with the heat-treating of chromium-vanadium steel. We have had better results with music-wire, the tensile strength of which is between 275,000 and 300,000 lb. per sq. in. I understand that this wire is made in America, from Swedish carbon-steel.

MR. DONKIN:—We cannot test every spring but we do test many of them. Some defective springs may escape, but the percentage has been very greatly reduced. In drawing music-wire, it is worked practically to its ultimate strength, and the microscope shows the longitudinal flow of the metal. We have had both the best and the poorest results with music-wire, and we require our springs to be uniform. The old method of heat-treating was to heat the springs on pans in a box-type furnace. In quenching they were picked up on a rod, and that would chill portions of the spring.

HEAT-TREATING COILED SPRINGS

We have designed a continuous furnace in which the springs are placed on trays which pass through two stages of heat and then tilt to a 45-deg. angle to dump the springs into an oil quench without coming into the open air. The springs then go through a washing-machine and are drawn for about 35 min. at about 700 deg. fahr. We believe that this method of heat-treating produces a better spring than the old method. Recently we secured about 5000 lb. of Swedish wire and had to reject all of it because it was seamy. We also have had springs made in Sweden, and their life-test at 3000 r.p.m. was 8 hr. We require that our springs give 30 hr. on this test, and we have had springs made from American wire that have lasted 500 hr.

A MEMBER:—I think most of the defects are due to the hair-line seams.

MR. DONKIN:—I think that is true. When we began to etch wire we found about 30 per cent of it seamy, and we traced the trouble back to the mill. We have tried cutting up whole coils of wire to find hair-lines. Etching the end of the wire uncovers 90 per cent of the defects. Die-scratched wire gives very poor results, an average of about 10 hr. on our life-tests.

CHAIRMAN GORDON:—Does the heat-treatment affect the period of surge?

MR. DONKIN:—No.

A. F. CARLSON[10]:—Does the Government or do aviation-engine manufacturers require special tests on valve-springs for transoceanic planes that are to fly 30 to 45 hr.?

MR. DONKIN:—Aircraft engines generally run at lower maximum-speed than automobile engines; I think the speed of the Wright J-5 engine is about 1800 r.p.m. This probably makes the design much easier; however, I believe two or three springs are used on the Wright engine for safety.

MR. CARVELLI:—When the Wright engine established the endurance record of 51 hr., it was running at about 1300 r.p.m., I believe. The aeronautic specifications of the Army and Navy call for a 50-hr. test, 45 hr. at 90-per cent and 5 hr. at 100-per cent load. Many aeronautic engines now run at 2000 to 2500 r.p.m. I believe that few cars would stand up for 50 hr. at 50 m.p.h.

MR. DONKIN:—We have made springs that would operate continuously for 500 hr. at 3000 r.p.m. Operation at constant speed is a much easier problem than at variable speed.

W. E. JOHN[11]:—Can we expect a spring maker to produce springs that will last 750 hr. at from 1000 to 1400 r.p.m.?

MR. DONKIN:—I think we can.

ROLLER LIFTERS FOR HEAVY SPRINGS

CHARLES PLEUTHNER[12]:—According to my experience, it is necessary to use roller-type push-rods with heavy springs. What has been Mr. Donkin's experience as to that?

MR. DONKIN:—Our tests have been with mushroom-type push-rods, and we have not studied that point.

MR. JOHN:—The roller-type valve-push-rod provides a larger bearing-surface and will give better service than the mushroom type, with good lubrication. At the point of the cam, with a mushroom-type push-rod, the lubricant is forced out and wear results.

QUESTION:—What is the analysis of the steel used?

MR. DONKIN:—We use S.A.E. No. 6150 steel. With $\frac{1}{8}$-in. wire, the heating period is about 12 min. and the drawing about 20 min. With 3/16-in. wire, the heating is 18 to 20 min. and the drawing about 40 min.

MR. CARVELLI:—I understand that Colonel Lindbergh had a broken valve-spring in Washington; valve-spring breakage is not uncommon in aircraft.

MR. DONKIN:—Springs will fail because of rusting. This can be prevented easily by rust-proofing by cadmium-plating, avoiding many breakages that are caused by rust.

MR. CARLSON:—Is it possible that some of the failures in transatlantic flights were caused by valve-spring breakage?

MR. CARVELLI:—I cannot say. On some aircraft engines sets of seven or nine valve-springs are used for each valve, and a safety lock is provided to keep the valve from striking the piston if the springs break. Flight may still be possible with one or two cylinders missing.

MR. JOHN:—If one of these multiple springs breaks, the pressure on the valve is released. According to my experience, the most common cause of a valve dropping into the cylinder is breakage at the end of the valve-stem.

Where space is limited, is length or diameter of the spring more important?

MR. DONKIN:—A certain minimum length is necessary for a spring. The diameter can be varied, but not the length.

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[11] A.S.A.E.—Engineering and sales, Buffalo Gasoline Motor Co., Buffalo.

[12] M.S.A.E.—Passenger-car engineer, Pierce-Arrow Motor Car Co., Buffalo.

THE DISCUSSION AT MILWAUKEE

J. C. SLONNEGER[13]:—While using an oscilloscope in studying crankshafts, I made some observations of valve-spring surge. The normal camshaft speed was 500 r.p.m. and the period of the spring was 5500 per min., that is, 11 oscillations per revolution of the camshaft. In this instance, the oscillation of the spring synchronized with the cam movement so that the motion imparted by the cam aided in building up the oscillation of the spring. At other than critical speeds the oscillation was not so bad. I also discovered that a small object such as the eraser on the end of a lead pencil would damp out the oscillation easily if placed against the spring.

W. G. CAREINS[14]:—Remarkable results are reported on racing cars with springs having a variable lead. What effect has valve-spring surge on the engine operation aside from spring breakage?

MR. DONKIN:—We have made a number of variable-lead springs, in which some of the coils are closed when the spring is compressed. Most of the racing-engine springs have also a rather low stress-range. The general tendency is for springs with uniform pitch to break near the fixed support. The idea of the variable-pitch spring was to cushion the effect at that end, and it has met with a fair degree of success. When a spring is surging violently, the valve is thrown open and there is a tendency for it to burn. There is also a tendency for the whole valve-mechanism to twist rapidly so that the valve seats with an abnormal rotary motion and digs into the seat. Surging also makes the push-rod leave the cam; and, if the timing is such that it strikes the cam always at the same place, there will be trouble from worn cams.

QUESTION:—Have any experiments been made to find whether the spring will vibrate in a bath of oil?

MR. DONKIN:—I think that such a bath would damp the vibrations, but it would be a rather clumsy arrangement and I believe that the problem can be solved more simply. I do not know that anyone has ever tried it.

MR. SLONNEGER:—What are the comparative results with multiple springs and laminated springs?

MR. DONKIN:—Most of my experience with such springs has been on a small airplane-engine which has seven springs in a circle around the valve-stem. The springs are small in diameter and are made from small music-wire. The assembly is costly and so very noisy that it would not be acceptable on an automobile. Inside retainers are necessary to prevent the springs from buckling, and these cause the noise. The objection to laminated springs is that they require too much room.

J. R. THONGER[15]:—Laminated springs have been used on racing-motorcycle engines and they operate well up to 6000 r.p.m., although the mass is greater than that of coil springs. These springs have been replaced first by multiple springs in a circle, and more recently by concentric springs.

THE DISCUSSION AT CHICAGO

O. W. YOUNG[16]:—Do the periods come in and go out with a small change in speed?

MR. DONKIN:—At low speeds a change of 5 r.p.m. is sufficient to eliminate a period, but at high speeds the ranges are prolonged so that it seems impossible to eliminate one period before another comes in. Formerly, spring makers were not able to give good service in connection with design of valve-springs. A few years ago we conceived the idea of having the engine manufacturer submit his valve train for us to work with in developing the spring, as each mechanism seems to have its own peculiarities. We have found no sure way of designing a spring without trial.

A. W. SCARRATT[17]:—On Packard aeronautic engines are not banks of seven springs used in place of single or compound springs?

MR. DONKIN:—Yes, one Packard engine uses a cluster of seven springs and another uses a cluster of ten. This was done to eliminate trouble from valve-spring breakage. Packard cars now are equipped with a new double spring, one wound inside the other, with metal retainers at the end. These springs have a high period and a high rate. The one trouble we found with springs of this type when we worked with them was breakage from bending stresses where the ends enter the retainers. We do not know how that has been eliminated in the Packard springs.

A VISITOR:—A valve-in-head engine that had been used about a year developed a surge at about 13,000 miles and was returned to us after running another 1000 miles. The surge occurred at about 45 m.p.h., or 2200 r.p.m. We changed successively the springs, the camshaft and the entire cylinder-head. The trouble was not corrected until the fourth cylinder-head was applied. They were all standard-production heads with overhead valves, and I can see no reason why the trouble was eliminated with one head and not with another. The valve push-rods also were changed.

MR. DONKIN:—With overhead valves we have discovered that the valve push-rod has a period that may cause vibration in the spring. We cannot cure this trouble by changing the spring, but we can cure it by changing the push-rod.

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[15] Beaver Mfg. Co., Milwaukee.

[16] M.S.A.E.—Assistant manager, Western division, Hyatt Roller Bearing Co., Chicago.

[17] M.S.A.E.—Chief engineer in charge of motor-trucks, International Harvester Co., Chicago.

Spectroscopic Study of Fuels and Analysis of Detonation Theories

By Dr. George L. Clark[1]

Chicago Section Paper — *Illustrated with* Chart

This paper reports continuation, along one line, of experiments described in a paper[2] previously presented by Dr. Clark, Robert H. Aborn and Elmer W. Brugmann at the Annual Meeting of the Society in 1927.

Samples of a number of different commercial gasolines were examined by means of the ultraviolet spectra of their detonation flames. This study yielded interesting and valuable information in regard to combustion, explosion and detonation; the action of detonation was studied, and complicated momentary reactions are indicated.

Dr. Clark has made a list of 12 theories of the action of knock suppressors giving the pro and con evidence in connection with each. He concludes that no single theory yet propounded seems entirely satisfactory; and he names three types of detonation, accounting for the complexity of the problem.

In addition to the paper, as given here, Dr. Clark repeated at the Section meeting much of the material of the 1927 Annual-Meeting paper to which reference is made. The discussion therefore is partly on his previous paper.

In two papers[2] already published, the method of studying the combustion of fuels in an internal-combustion engine by means of the ultraviolet spectra of the flames has been presented. In the experiments reported, a small quartz window is mounted in the cylinder of the engine and the radiation emitted is analyzed by means of a photographic quartz-prism spectograph. This fundamentally scientific method, applied to the problems of detonation and its control, has yielded some interesting and valuable items of information, of which the following are of especial importance:

(1) Combustion, explosion and detonation are clearly distinguished by the spectra of radiation in the ultraviolet. In detonation or "knock" the spectra run down into the ultraviolet as far as 2200 Ångström units.[3]

(2) Knock suppressors such as lead tetraethyl absorb radiation in the far ultraviolet and invariably shorten the spectra, while knock inducers tend to accentuate short-wave radiation.

(3) Radiation accompanying detonation is emitted during practically the entire first two quarters of the engine stroke, whereas the spectra have the same length and intensity for all four quarters of the stroke when the engine is operating without knock in the presence of detonation suppressors. Lead tetraethyl, iodine and aniline, though differing widely in chemical nature, act alike in this respect.

(4) The emission spectrum lines of lead, which appear when the fuel contains only the slightest trace of lead tetraethyl, are not usually evident after the first quarter of the engine stroke, indicating that the action of the compound in suppressing detonation occurs very early in the oxidation reaction.

Indicates Kind, Not Intensity, of Reaction

As all the results indicate that the ultraviolet spectra are very sensitive in indicating the *kind* of reaction, rather than the *intensity* of a given type, the statement has been expressly made that the observed phenomena, particularly the length of the spectra, do not necessarily indicate the efficiency of various brands of gasoline. However, it has seemed of interest to compare a series of 13 brands of gasoline to ascertain whether they might be graded according to knocking tendency from the spectra of the detonation flames in a single-cylinder Delco engine. To make the comparisons complete, the knock was measured in each case with a Midgley bouncing-pin, and data on the constitution and distillation were available.

The engine was run under such conditions that even the best of the fuels produced a measurable detonation; hence, the experiments measure degree rather than kind of oxidation reaction. The constancy of operation of the engine was fully as dependable as in the runs reported in the preceding paper. Photographed spectra from the tests are reproduced in Fig. 1, together with the data on knock as measured with the Midgley indicator, the average temperature-reading in millivolts, the load in watts, and the revolutions per minute of the engine. Typical data, obtained on sample J by photographing the radiation during the first and second halves of the engine stroke, are presented in Table 1. The data and spectra are arranged in the order of increasing knock, measured under the same conditions. In Table 2 are given the constitution, break-up and distillation data of the fuels, arranged in the same order as in Fig. 1. A study of Fig. 1 and Table 2 reveals the following facts:

(1) With the exception of sample C, which contains lead tetraethyl, the successive spectra, particularly for the first half of the stroke, are not widely different in structure or extension into the far ultraviolet (about 2500 Ångström units), illustrating the fact that detonation in all but the single case is a common chemical reaction, and that a strict rating of fuels when all are detonating is not directly possible. This seems to indicate that the detonation is asso-

[1] Professor of chemistry, University of Illinois, Urbana, Ill. Part of this work was carried on at the Massachusetts Institute of Technology, with the assistance of C. L. A. Wynd and H. F. Haase.

[2] See The Journal, February, 1927, p. 291; and *Industrial and Engineering Chemistry*, May, 1926, p. 528.

[3] One Ångström unit = 0.0000001 cm. (0.0000003937 in.).

ciated with a secondary compression-wave, and not directly with the flame and the oxidation reaction which produces it.

(2) All the fuels except samples L, C and D are distinguished by a large difference in flame spectra between the first and second halves of the strokes, in that the latter spectra are far shorter (3500 Ångström units) and less intense than those for the first half (2500 Ångström units). In general, the detonation is stronger as the difference is greater, which indicates that most of the energy is liberated at the beginning of the reaction. It is a remarkable fact that the three fuels which are not purely hydrocarbons are clearly differentiated. Sample L is made from sample M, 65 per cent, and alcohol, 35 per cent; D is 60 per cent M and 40 per cent benzene; and C contains $Pb(C_2H_5)_4$. With these samples the second-half spectrum extends to the steam lines at λ[4] 3064, and even beyond. Even though these fuels are knocking, the addition agents are exercising a strong effect in equalizing the reaction throughout the stroke. For sample C, the first and second spectra are identical in length and structure, the only difference lying in the weaker intensity for the second half of the stroke. Separate experiments have demonstrated that, as the engine is operated so that there is less and less knock, this weaker spectrum becomes more and more intense until, in the ideal condition of immeasurable knock, the first and second spectra are identical in intensity as well as in structure and wave-length range. In other words, the reaction proceeds uniformly from beginning to end of the stroke. Spectra L, C and D are further distinguished by the fact that the absorption (dark) bands and lines appearing principally between 3600 and 3900 Ångström units for all other fuels in the second-half-stroke spectra are not present. The full significance of this fact cannot be fully understood until the bands are measured, although a different mechanism is indicated.

(3) For sample L, which knocked least, the first-half-stroke spectrum runs as far into the ultraviolet as for any other more strongly detonating fuel, if not farther. This spectrum appears to be continuous, as it might be from any intensely hot flame. As a matter of fact, this alcohol fuel does burn with a hotter flame than the other fuels, and it was quite difficult to control the temperature of the engine. The benzene fuel D produced a much cooler reaction. The principal difference between samples L, D and M—which contain the same basic hydrocarbon fuel, a straight-run gasoline from Pennsylvania crude—is to be found in the spectra for the second half, as already noted. It is quite evident that the spectra for the last half of the engine stroke are more sensitive indicators of differences than are those for the first half.

(4) The emission lines of lead appear as usual in the spectra of sample C, quite strongly for the first half of the stroke and weakly for the second half. Five lines appear in the former, of which the three at λλ 4058, 3683 and 3639 are the persistent lines of lead that are observed also in the second spectrum. The additional lines at λλ 3614 and 4009 may be due to tungsten from the spark-plug.

(5) There is no simple parallelism between knock data, spectra, fuel constitution, and distillation properties. In general, an increasing content of saturated hydrocarbons is accompanied by an increasing tendency to knock, as shown by the data in Table 2. Samples E and F, with the highest volatilities except for the fuels containing benzene or alcohol, are intermediate in their detonation. The spec-

[4] λ = wave length in Ångström units.

TABLE 2—CONSTITUTION, BREAK-UP, AND DISTILLATION DATA OF THE FUELS STUDIED

	Break-Up			Distillation, Percentage at Deg. Fahr.		
	Olefins, Per Cent	Unsaturated Naphthenes, Per Cent	Saturated Hydrocarbons, Per Cent	221	284	392
L[6]	38.3	33.3	28.4	60.5	74.0	96.5
C[7]	11.7	65.4	22.9	26.5	52.0	92.0
A	18.3	65.4	16.3	28.0	48.0	93.0
B	9.2	81.7	9.1	31.0	61.5	97.5
D[8]	13.3	71.1	15.6	63.0	78.0	97.5
K	6.7	69.0	24.3	20.0	52.0	93.0
E	10.8	62.4	26.8	36.5	76.5	98.0
F	12.5	61.3	26.2	30.0	65.0	98.0
H	10.0	63.0	27.0	28.0	56.5	98.0
I	9.2	65.4	25.4	28.0	53.0	98.0
G	8.3	62.4	29.3	26.5	52.5	92.5
M[9]	5.6	62.2	32.2	21.5	59.0	95.5
J	7.5	75.8	16.7	26.5	51.5	91.5

[6] Containing 35 per cent of alcohol.
[7] With ethyl fluid.
[8] Containing 40 per cent of benzene.
[9] Straight-run gasoline from Pennsylvania crude-oil.

TABLE 1—COMPLETE DATA-SHEET FROM A REPRESENTATIVE RUN

	Sample J—First Half of Stroke				*Sample J—Last Half of Stroke*			
Time, Min.	Volts	Amperes	Engine Speed, R.P.M.	Knock[5]	Volts	Amperes	Engine Speed, R.P.M.	Knock[5]
0	78.8	10.3	1,020	2.55	82.0	10.5	1,040	2.65
5	79.0	10.4	1,020	2.67	80.5	10.2	1,020	2.72
10	79.5	10.5	1,040	2.74	80.2	10.2	1,030	2.73
15	79.0	10.4	1,040	2.73	80.2	10.25	1,030	2.75
20	79.3	10.45	1,045	2.73	80.1	10.3	1,030	2.75
25	79.3	10.45	1,055	2.78	80.8	10.35	1,040	2.60
30	79.3	10.45	1,050	2.80	79.8	10.15	1,020	2.78
35	79.3	10.4	1,050	2.78	79.8	10.15	1,030	2.76
40	78.7	10.4	1,055	2.83	79.0	10.0	1,030	2.73
45	78.7	10.35	1,050	2.80	77.0	9.8	1,010	2.72
50	78.7	10.4	1,060	2.83	76.0	9.5	1,000	2.68
55	78.5	10.35	1,050	2.82	77.0	9.65	1,030	2.75
60	78.5	10.35	1,060	2.83	77.3	9.8	1,040	2.72
65	78.5	10.35	1,060	2.80	78.7	9.95	1,050	2.74
70	78.2	10.35	1,055	2.82	78.0	10.0	1,040	2.76
75	78.2	10.3	1,060	2.80	77.5	9.9	1,030	2.73
80	78.0	10.3	1,055	2.83	77.5	9.9	1,030	2.70
85	78.0	10.25	1,060	2.86	76.5	9.8	1,020	2.72
90	78.0	10.25	1,060	2.88	76.5	9.8	1,020	2.70
Averages	78.7	10.37	1,050	2.84	78.7	10.01	1,028	2.72
Load, 816 watts.					788 watts			

Note—The temperature was controlled with the help of a very sensitive thermocouple and was kept constant during all comparative runs. The total variation during the sample-J runs was from 11.10 to 11.25 millivolts.

[5] The knock was measured by the Midgley bouncing-pin method. The figures refer to the amount of gas evolved, in cubic centimeters per minute.

tra for the second half of the stroke are unusually short and faint, but the volatility cannot be said to be directly related to knock. These facts are but further evidence of the complexity of the problems of the cause of detonation and the mechanism of its suppression or reduction by addition agents.

Theories of Knock Suppressors

Following is a list of theories of the action of knock suppressors, with the evidence supporting each theory and that against it arranged in parallel columns.

(1) Colloidal metal deposition on sharp corners and edges

Pro	*Con*
(*a*) A single French experiment	(*a*) Experiments in the United States, negative
(*b*) General analogy to known effect of sharp points, sand and the like in increasing the velocity of the explosion wave to the point of detonation	(*b*) Does not explain why knocking begins instantly upon the substitution of a knocking fuel for one containing suppressor, although lead and oxides still cling to the walls
	(*c*) Does not explain the necessity for organic valences
	(*d*) Does not account for the suppressing action of aniline and iodine, containing no metal
	(*e*) Does not account for knock induction (Do nitrites make the steel edges sharper?)

(2) Pyrophoric colloidal particles acting as miniature spark-plugs

Pro	*Con*
(*a*) The known fact that increasing the number of spark-plugs in an engine decreases knocking,[10] by instituting many waves which destructively interfere and smooth out the reaction	(*a*) Absolutely negative results in the United States from experiments the same as those of Sims and Mardles
(*b*) Experiments of C. J. Sims and Mardles,[11] indicating that iron, lead or nickel solution in gasoline has the same antiknock effect as tetraethyl lead, $Pb(C_2H_5)_4$, iron carboxide, $Fe(CO)_5$, and nickel carboxide, $Ni(CO)_4$	(*b*) Does not account for the suppressing action of aniline, iodine and the like; nor of inducers
(*c*) Theory and experiments of W. H. Charch, Edward Mack, Jr., and C. E. Boord[12] that spreading the oxidation process throughout a large volume by pyrophoric metal particles or easily oxidizable hydrocarbon radicals in amines, such as aniline, decreases detonation	(*c*) Does not account for the fact that $Pb(C_2H_5)_3Cl$ and $Pb(C_2H_5)_2Cl_2$ are three-fourths and one-half as effective as $Pb(C_2H_5)_4$
	(*d*) Sims and Mardles obtained negative results with all colloidal solutions of carbon, gold, silver, copper, cobalt, chromium, tungsten, uranium, cerium, aluminum, iron, nickel, lead and mercury—excepting solutions prepared from $Fe(CO)_5$, $Ni(CO)_4$, and $Pb(C_2H_5)_4$—with the possibility of some residual unchanged compounds with known great suppressing power

(3) Electron absorption by heavy metals

Pro	*Con*
(*a*) It is reasonable that ionization should occur thermally and from chemical reactions in a system of high energy	(*a*) Proved wrong experimentally by G. L. Clark, E. W. Brugmann and W. C. Thee; confirmed since by S. C. Lind, Garner and Saunders
(*b*) Experiments of G. L.	

(3) Electron absorption by heavy metals (*Continued*)

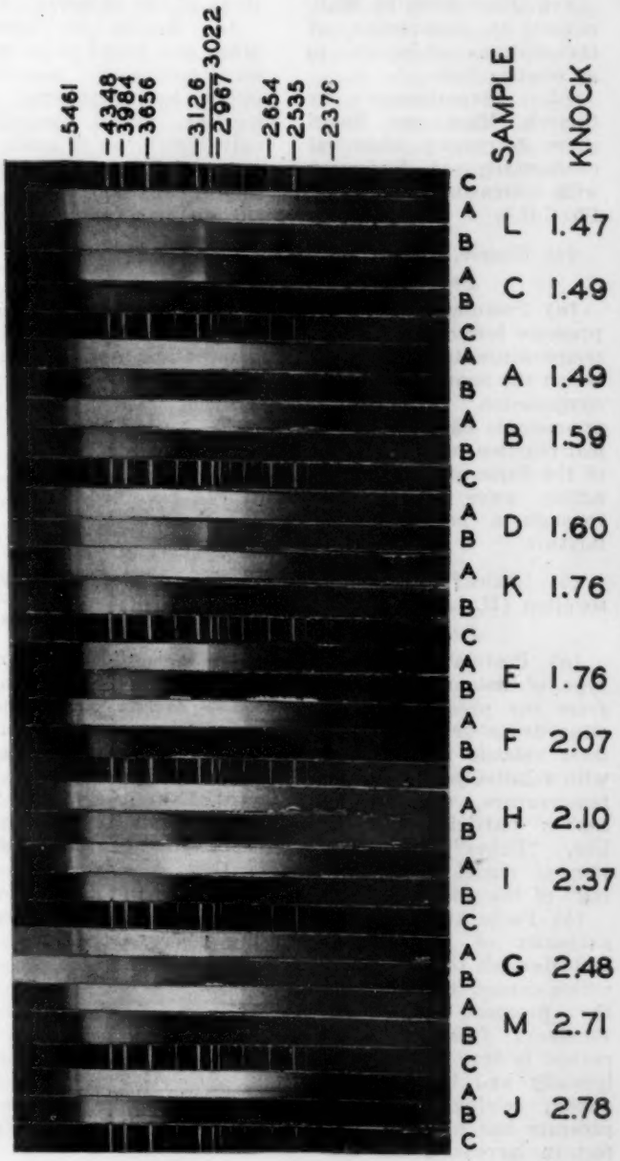

Fig. 1—Spectra Photographed from Fuel Tests

The Scale Figures Are Ångström Units. Spectra Marked *A* Were Taken During the First Half of the Stroke, and Those Marked *B* Were Taken During the Second Half. Mercury Spectra, Marked *C*, Are Inserted for Reference. The Knock Was Measured by a Midgley Indicator. The Speed and the Load on the Engine, with the Various Samples, Were as Follows:

Sample	Engine Speed, R.P.M.	Load, Watts
L	1,075	831
C	1,043	813
A	1,030	811
B	1,033	800
D	1,080	842
K	1,065	835
E	1,038	815
F	1,020	820
H	1,042	799
I	1,021	804
G	1,060	791
M	1,038	805
J	1,050	816

[10] See The Journal, June, 1921, p. 561.

[11] See *Transactions of the Faraday Society*, October, 1926, p. 363.

[12] See *Industrial and Engineering Chemistry*, April, 1926, p. 334.

(3) Electron absorption by heavy metals (*Concluded*)

Pro	*Con*
Wendt and Grimm, indicating that ionization is far smaller in the presence of $Pb(C_2H_5)_4$.	(*b*) Also open to the objections that the effects of aniline, iodine and the like are not explained, nor are those of the inducers
(*c*) Observation by Malinovski of suppression of the explosion of benzene in an electric field	(*c*) Results of Charch, Mack and Boord prove that an antiknock material, either lead tetraethyl or benzene, affects ionization only insofar as it tends to suppress detonation, rather than acting *per se* in removing ions from gases
(*d*) Experiments by Charch, Mack and Boord show decreasing electrical conductivity or ionization with increasing amounts of $Pb(C_2H_5)_4$.	

(4) Simple, positive catalysis

Pro	*Con*
(*a*) Postulates that suppressors lower the ignition temperature to a point at which the heat of adiabatic compression could cause appreciable but slow chemical reaction to occur ahead of the flame so that the reaction wave would pass through a partly burned mixture	(*a*) No necessary relationship between ignition temperature and tendency to detonate proved by experiment
	(*b*) Avoids the issue of mechanism

(5) Nuclear condensation prevention or preferential adsorption (H. L. Callendar, November, 1925)

Pro	*Con*
(*a*) Postulates that one type of detonation results from the presence of nuclear drops or particles of least volatile hydrocarbons with relatively low ignition temperature, adsorbed on carbon particles and the like. "Dopes" delay ignition of nuclei by "poisoning" of the nuclei.	(*a*) It is difficult to relate preignition and detonation — carbon disulphide preignites without detonation, and ether detonates without preignition
(*b*) Facts known on the authority of Lord Kelvin and Maxwell that: Condensation cannot occur without the presence of nuclei (smoke); freshly formed carbon is very active catalytically and in absorbing vapor; raising the initial pressure has a marked effect in increasing the tendency to detonate; hydrogen most readily ignites on platinum-black; and benzene in rich mixtures detonates at high initial pressures and low temperatures	(*b*) Exactly opposite in some respects to pyrophoric theory for *decreasing* detonation
	(*c*) Research needed, but this appears to be a promising theory

(6) Simple negative catalysis (Thomas Midgley, Jr.)

Pro	*Con*
(*a*) Postulates that substances in gaseous form decrease the reaction velocity of burning fuel	(*a*) Avoids the issue of mechanism
(*b*) According to C. A. Woodbury, A. T. Canby and H. A. Lewis, the pressure in front of the wave at one stage is greater than that behind it by 0.4 lb. per sq. in.	(*b*) Experiments with indicator diagram show no effect of antiknock substances on flame velocity; also recently proved in beautiful experiments of P. Lafitte and P. Dumanois[13]
	(*c*) Cannot explain satisfactorily the necessary organic valences, or knock induction
	(*d*) The pressure gradient mentioned in (*b*) under *pro* is in the wrong direction and only 1/1000 that of a detonation

(7) Catalysis of preferential reaction route, or hydroxylation

Pro	*Con*
(*a*) Considerable chemical evidence for different oxidation routes, such as hydroxylation or complete oxidation, in the burning of hydrocarbons; on the authority of numerous papers by Bone and others	(*a*) Experimentally difficult to prove finally. H. L. Callendar, R. D. King and Mardles, of the British Air Ministry Laboratories, fail to find any traces of hydroxyl compounds formed in oxidation
(*b*) Ultraviolet spectra gives unmistakable evidence of different reactions with and without suppressors	(*b*) Does not postulate mechanism of catalysis
(*c*) New experiments in our laboratory on slow oxidation of fuels show that hydrocarbons go through an alcohol stage in the presence of $Pb(C_2H_5)_4$, the final liquid product being greatly different from that formed in the absence of an antiknock agent	(*c*) Difficult to extend to knock inducers

(8) Catalytic poisoning (Schlesinger)

Pro	*Con*
(*a*) Postulates that the metal walls of the combustion chamber act as positive contact catalysts of reaction velocity, and these are poisoned by deposits from the suppressor	(*a*) Mercury and sulphur, known to be catalyst poisons, are knock inducers
(*b*) Organic amines known to be mild poisons of catalysts; and iodine, selenium and lead to be strong ones	(*b*) No appreciable lag in the appearance of knock when fuel without a suppressor is introduced suddenly
	(*c*) Detonation occurs in glass as well as in metal vessels

(9) Radiation

Pro	*Con*
(*a*) Postulates that gaseous knock-suppressors absorb radiations from flame, which otherwise photochemically activate molecules ahead of the flame and accelerate reactions by splitting hydrocarbons into a more reactive condition	(*a*) Difficult to extend to knock inducers
(*b*) Considerable photochemical evidence; experiments of David[14] prove that the reaction rate greatly	(*b*) Direct proof lacking, and many experiments required

[13] See *Comptus Rendus de l'Academie des Sciences*, vol. 186, (1928), p. 146.

[14] See *Transactions of the Faraday Society*, October, 1926, p. 341.

(9) Radiation (*Concluded*)

Pro

accelerates by absorption of infra-red wave-lengths corresponding to absorption bands of fuel gas

(*c*) Ultraviolet spectra furnish very direct proof: first, that tetraethyl lead, aniline, iodine and all other suppressors absorb far-ultraviolet radiation during detonation, so that the spectrum is like that of explosion; second, that knock inducers increase the intensity of the spectra in the far-ultraviolet; third, that ultraviolet spectra during detonation, are very strong for the first quarter of the stroke, weaker for the second quarter, and very weak for the third and fourth quarters, showing the rapidity of the evolution of the energy, while, with all knock suppressors, the four quarters become exactly alike in length and intensity of spectra, showing uniformity of reaction throughout stroke; and, fourth, that spectral lines for metallic lead—with tetraethyl lead—appear only in the spectrum for the first quarter, showing that glowing metallic particles, if formed, do not persist

(*d*) Ultraviolet light of strong intensity, focussed through a quartz window into the combustion mixture, has been found to increase detonation

(*e*) Detonation suppressors, as well as familiar antioxidants such as hydroquinone, destroy the fluorescence of substances irradiated with ultraviolet rays[15], and the like.

(*f*) The formation of peroxides in hexane-air and ether-air mixtures is assisted by ultraviolet light at 150 to 250 deg. fahr., if not counteracted by suppressors (H. L. Callendar, 1926)

(10) Opposition to auto-oxidation and peroxide formation

Pro

(*a*) Suppressors act as antioxygen catalysts in the liquid phase—an extension of the comprehensive theory of Charles Moureu and Dufraisse—acting according to a chain mechanism, as follows:

A (fuel) + $O_2 \rightarrow A(O_2)$ (peroxide)

$A(O_2) + B$ (catalyst) $\rightarrow A(O) + B(O)$

$A(O) + B(O) \rightarrow A + B + O_2$

(Auto-oxidation is accompanied by peroxide formation, which detonates the mixture as would fulminates, and peroxides are prevented by suppressors[16].)

(*b*) Peroxides which are strongly detonating are formed with amyl and ethyl ethers, paraffin hydrocarbons, and the like, but not with alcohol, benzene, aniline, and others; while such formation is absolutely inhibited by knock suppressors, according to Callendar. Peroxides added to fuel greatly increase detonation. Liquid drops form peroxides more easily than does vapor, thus relating the theory to the nuclear condensation theory

Con

(*a*) The theory is very convincing except as to the exact mechanism by which the suppressors eliminate peroxide formation. The Callendar theory, that metal deposited by decomposition or droplets prevents adsorption of peroxides, is inadequate to explain the positive action where the fuel, pure hexane, is completely vaporized. No mechanism which takes into account changes to the Pb $(C_2H_5)_4$ molecule, for example, is postulated by Moureu and Dufraisse

(10) Opposition to auto-oxidation (*Concluded*)

(11) Free-radical theory

Pro

(*a*) Postulates that suppressors act as in several of the preceding theories by forming momentarily free radicals:

$Pb(C_2H_5)_4 \rightarrow Pb + 4\ C_2H_5$

the final products being $Pb + 2\ C_4H_{10}$ in heat decomposition; $I_2 \rightarrow 2I$; and so on. Radiant energy may be absorbed in this process, thus accounting for the necessity for organic valences

(*b*) Based upon known chemical facts of existence of free radicals, on the authority of M. Gomberg and others

Con

(*a*) Difficult to prove experimentally

(*b*) Still difficult to explain inducers

(12) Inhibition of chain reactions

Pro

(*a*) A theory, due to Christiansen and extended by Bäckström, H. S. Taylor and others, that in chain reactions the energy of the reaction products is transferable to molecules of reactant, thus actuating them, so that reaction between single pairs of molecules may suffice to promote a sequence of similar reactions many thousands in number. An inhibitor,

Con

(*a*) Not yet demonstrated for hydrocarbons and antiknock substances; experimental technique for detection of minute changes is very difficult

(*b*) Open to the same objections as the simple negative-catalyst theory (6).

[15] See *Comptus Rendus de l'Academie des Sciences*, vol. 184, (1927), p. 1121.

[16] See *Comptus Rendus de l'Academie des Sciences*, vol. 184, (1927), p. 8.

(12) Inhibition of chain reactions (*Concluded*)

Pro

such as $Pb(C_2H_5)_4$, breaks the chain of reactions

(*b*) Proved in oxidation of aldehydes and aqueous solutions of sulphites. Chains broken by oxidation of molecules of inhibitor alcohol

(*c*) Best proved in photo-sensitive reactions, thus linking this theory with the radiation theory (9)

No single theory is yet entirely satisfactory. The reactions of two or more theories may be operating together.

The radiation theory (9), the peroxide theory (10), and the chain-reaction inhibition theory (12) seem to be the most promising.

The nature of detonation itself must be more thoroughly understood. There are evidences of three types of detonation, which account for the complexity of the problem. (*a*) *pressure-wave*—development of pressure difference into a compression wave of sufficient intensity to fire the heated mixture; (*b*) *nuclear*—drops of particles of low ignition-temperature, on carbon, for instance; (*c*) *molecular*—the temperature of the completely vaporized or gaseous mixture raised to induce direct molecular combination.

THE DISCUSSION

ROBERT E. WILSON[17]:—I notice a surprisingly large difference in the spacing of the different hydrocarbon chains between the lead soaps and the corresponding hydrocarbons, the spacing in the soaps being apparently much longer. That seems strange according to ordinary theories of chemical structure. I wonder if Professor Clark has a theory for this, and if it can be due to something like rows of soldiers standing on each other's heads. If there is an active group at one end, the heads would be together and the feet together in alternate rows, so that the length measured between the planes of active groups is really double the length of the molecule rather than its actual length.

GEORGE L. CLARK:—Mr. Wilson is an X-ray expert, and he is exactly right. In a hydrocarbon, the ends are alike, but in the acids and soaps a double layer is formed, because the carboxyl group is active. In the lead soaps we have the further complication of two members, like two legs on one body. In some instances, like tri-glycerids appearing as greases, there are three members; but it has been amply demonstrated that the two hydrocarbon ends of the glycerids are together and the two active alcohol ends also are together. It is actually possible, by means of the X-ray intensities, to take a long chain like a ketone, with only one CO group, and measure exactly where the CO group is in the chain; because the oxygen is so much more active in its diffraction of X-rays than is the carbon or the hydrogen. The same is true of other corresponding compounds.

WALTER MARTINS[18]:—Have you made any experiments with detonation, using the same compression-ratio, speed and load in two engines with differently shaped combustion-chambers; and was any difference in the amount of knock observed? Various manufacturers are trying to overcome knocking with increased compression by changing the shape of the combustion-chamber, and apparently they are eliminating some of it.

DR. CLARK:—Unfortunately I have not been able to try this, because only one engine was available. In that engine we could vary the compression-ratio, but not the form of the combustion-chamber. Such an experiment should be made. It is well known that the shape of the combustion-chamber does affect knocking. It is the general theory that the chamber should be smooth and spherical, as nearly as possible, but some of the new high-compression engines are far from that. The introduction of hot-spots, multiple spark-plugs and other features help to overcome the effects of the incorrect shape.

GASOLINE BEING IMPROVED

GEORGE R. WILLY[19]:—Another factor that influences the design of the combustion-chamber is the increased performance demanded. Were it not that the refining companies are producing gasolines of a very advanced composition, we should not be able to use such high compression and still avoid knocking. The latest combustion-chamber designs are made to eliminate knocking and to increase the performance.

M. J. KITTLER[20]:—With any knocking agents other than tetraethyl lead, such as iodine and aniline, is there some element or group that retains its identity during the first part of the stroke, like lead, and loses it in the last part?

DR. CLARK:—There is no evidence to that effect unless the fine part of the spectrum indicates it. There is some opinion supporting the presence of free radicals; for example, the tetraethyl might break up instantaneously or very rapidly into lead and the C_2H_5 radical, and aniline might break up into free radicals. Prof. H. S. Taylor recently suggested the possibility that iodine does break up, I_2 into 2I, at high temperature. It is almost impossible to prove such a theory, because the condition might exist for such a short time that even so rapid an instrument as the spectroscope might not register anything that could be interpreted. There is nothing else to indicate the mechanism of the reaction, but many people believe that lead tetraethyl breaks up and produces colloidal lead.

I have had correspondence for some time with Captain King, of the Laboratory of the British Air Ministry, where they long held to the theory that lead tetraethyl, nickel carbonyl and some other knock suppressors function because their decomposition produces colloidal lead or nickel which acts catalytically or becomes incandescent and acts like tiny multiple spark-plugs. The experiments of the Ethyl Gasoline Corporation and Dr. Graham Edgar seem entirely to disprove this theory. In addition, this theory did not at all account for the action of aniline or idoine or any

[17] M.S.A.E.—Member of research council, research laboratory, Standard Oil Co. of Indiana, Whiting, Ind.
[18] A.S.A.E.—Owner and general manager, Automotive Service Co., Chicago.
[19] E.S.S.A.E.—Mechanic, Community Motors, Chicago.
[20] E.S.S.A.E.—Armour Institute of Technology, Chicago.

of the other compounds that have an entirely different structure. We hope to make a final test of this colloidal-metal theory. I have tried it two or three times with no result. There may be some colloidal lead that helps a little, but that is not the real reason for the value of lead tetraethyl. Many experiments are still to be made along this line. They involve some of the most difficult chemistry, trying to distinguish a reaction in what probably is a series of reactions taking place very rapidly.

Another theory, also from England, is that peroxides are formed. It is well known that peroxides are very unstable, really explosive. According to this theory, the formation of peroxide is an intermediate step which causes detonation in the oxidation of the carbon. Lead tetraethyl may enter and poison the peroxide or break it up catalytically. It is almost impossible to devise experiments to show the existence of these various compounds that might be formed and broken down again instantaneously. All of our experiments are integrating experiments.

Industrial Applications Growing

BENJAMIN S. PFEIFFER[21]:—To what extent has X-ray analysis of castings and parts been adopted in manufacturing plants?

DR. CLARK:—It seems to be a slow process to get anything like this adopted; yet the progress has been rather rapid. It has been only two or three years since its development began, and there is a great deal of interest in it among manufacturers. Some men will have nothing to do with it because they are afraid it will make things harder for them, but several industries have taken or are taking steps to introduce X-ray laboratories. I have now several requests for men to establish X-ray laboratories; but no men trained for the positions. Several manufacturers are sending men to us to be trained.

I am afraid that we are lagging behind the Germans in the introduction of the process into industry. There recently was a large exhibit or congress in Berlin devoted to the use of the X-ray for the benefit of manufacturers; and we were glad to send to them some of our photographs, as they requested. They are making considerable progress because many of their research institutions are endowed by the government.

Much is yet to be done in the way of developing simple apparatus and training men; men with experience now are the commodity most needed, and several universities are attempting to train men to meet these industrial problems. Many industries are consulting various established laboratories regarding certain problems to see whether the X-ray will offer any solution, and a number of such investigations are being begun at the University of Illinois; for example, the first photographs we have taken of spark-plug porcelains detect the strains in the material and promise to lead to a proper treatment for their elimination. The manufacturers have perfected the spark-plug porcelains as far as they can; they are now facing a stone wall, and this tool will take them on farther.

I do not mean to say that X-rays will, in any condition, solve problems that nothing else can solve. Many think of it as a last resort, but I think of it as a helpful tool. At present it is too expensive to use as a testing method, but its results are well worthwhile for developing a technique for a given manufacturing process, particularly for such ends as ultimate structure, strain, grain size and proper annealing.

This is a great age in which to live, and this is a great subject on which to work. It is thrilling to see the light dawn on some industry that asks for help and says that it is ready for an X-ray laboratory and a man. Everything we do on an inorganic piece of metal may help toward the advance of the use of the X-ray on living matter, in the treatment of cancer and disease, the alleviation of pain, and the real understanding of X-ray therapy. There are many disappointments, but the cases in which X-rays have really helped in the solution of a problem make all the hardships well worth enduring.

Precautions Required with X-Rays

MR. MARTINS:—In using X-rays on loaded shells, is there any danger of creating static electricity inside the shells from the high-frequency current and causing an explosion?

DR. CLARK:—The current would be well screened and the high-tension apparatus could be away in another room. Everything would have to be well protected in a case like that, but the X-rays themselves would have no bad effects.

DR. WILSON:—It is impossible to generate any static current inside a metal shell.

QUESTION:—Do you use lead chambers in taking these pictures?

DR. CLARK:—We enclose the X-ray tube in a heavy lead box and the beam comes out through a very fine pinhole. The photographic plates also are surrounded by lead, so there is very little danger. In all our apparatus the transformer now is underneath, and there is only a short high-tension lead in the middle of the apparatus, all of the outside being grounded.

[21] M.S.A.E.—Consulting engineer, Chicago.

Can You Use Helium?

NEW uses are being sought for helium, which is now available for industrial purposes. Its unique properties will doubtless soon find numerous applications. Helium has nearly the lifting power of hydrogen, together with the inestimable advantage of being absolutely non-inflammable. It is not only more inert than nitrogen, but has the lowest solubility in water of any gas known.

Among the interesting properties of helium that may suggest new uses are complete chemical inertness, a specific gravity less than one-seventh that of air, thermal conductivity over six times as great as that of air, high specific-heat, the lowest boiling-point known, namely, — 267.8 deg. cent. (— 450 deg. fahr.), and the ability to conduct sound nearly two and a half times as rapidly as air.

The story of helium affords a striking example of the way in which unexpected values accrue from fundamental research. The gas was first discovered in the sun through the spectroscopic observation, by Janssen and Lockyear, of the solar eclipse of Aug. 18, 1868. In 1894, Rayleigh and Ramsay discovered argon in the atmosphere, and during the following year Ramsay, continuing his search for argon, found helium in the mineral cleveite. The present commercial source is certain gas wells in our Southwestern States.—Industrial Bulletin of Arthur D. Little.

Supercharger Applications

Two papers on the subject of supercharging were presented at the meeting of the Indiana Section held March 8, 1928. One, by Louis Schwitzer, dealt with the general applicability of the supercharger to automotive vehicles; the other, by David Gregg, recounted the actual performance of a supercharged passenger-car. Both papers are printed herewith, together with the discussion which followed their presentation. For the convenience of readers, abstracts of the papers and of the discussion precede the text.

The Application of Superchargers to Automotive Vehicles

By Louis Schwitzer[1]

MOST passenger automobiles are overpowered and probably 80 per cent of such vehicles operate at less than 35 m.p.h. for 90 per cent of the time, according to the author. At 30 m.p.h. an average 3000 to 3500-lb. passenger-car requires from 12 to 15 hp., but the engine carried is capable of developing from 50 to 55 hp. The result is that the car is operated for the greater part of the time at one-third to one-quarter throttle opening. Full power is needed only for accelerating and hill-climbing; during the remainder of the time the excess weight of the engine and other parts must be carried at a loss of efficiency. The author maintains that smaller engines can be used advantageously when equipped with superchargers, the supercharger being used only when excess power is required. Curves and a table are given to show the results of comparative tests with and without a supercharger, and views are shown of the design and construction of a supercharger believed by the author to possess special advantages.

IT is practical and economical to use superchargers on the average passenger-car, motorcoach or motortruck. Although the problem of supercharging is interesting in itself, industry and the public are interested only in the question that will decide the success of supercharging: What can be gained by its use and how much can be saved?

Probably 80 per cent of all passenger automobiles are driven 90 per cent of the time at less than 35 m.p.h. Why, then, penalize the entire industry and 80 per cent of all operators with unnecessarily long wheelbase, extra burden in car weight, and waste in operation? The average 3000 to 3500-lb. passenger-car traveling at 30 m.p.h. requires from 12 to 15 hp. Most of the engines used in these cars, at the engine speed necessary at this car speed, will develop from 50 to 55 hp. according to the design. During the greater part of the time the cars are therefore operated at one-third to one-fourth throttle opening. No wonder the fuel consumption rises from 0.7 lb. to 1.3 or 1.4 lb. per hp-hr., or practically twice what it should be.

Why are such large engines used in these cars? Not because the advertising and sales departments and a few owners think that a speed of 75 m.p.h. is essential, but because excess power is necessary for accelerating and hill-climbing. The average road-speed during the last two or three years has increased from 30 to 45 m.p.h. A great many trucks are also traveling at these speeds. To be able to pass this procession, extremely rapid acceleration between 35 and 60 m.p.h. is required. This is far more important than the much-advertised 5 to 25-m.p.h. acceleration that can be satisfactorily obtained with any car, if necessary, in a lower gear, which is always used if the speed is reduced to 10 m.p.h. or a stop is made for a traffic signal.

[1] M.S.A.E.—President and chief engineer, Schwitzer-Cummins Co., Indianapolis, Ind.

Supercharged Small Engines versus Large Engines

To meet the demand for top-notch performance, engines of large piston-displacement must be used. The resulting waste, however, is not only in the size of the engine, but in everything else that enters into the construction of the car. Oversize engines need large valves, extra length of cylinder-block, and higher lift and heavier valve-springs, with the accompanying difficulty of keeping the valves from warping and of augmenting the cooling problem. The increased weight of the valve mechanism presents a difficult problem in keeping it from surging, particularly at high engine-speeds, and from pounding out the seats, not to mention the stress on the driving mechanism. Cam outlines are necessary that will provide the largest possible openings in the shortest possible time, at the expense of quietness of operation. Large manifolds and carbureters are required, and it takes real acrobatics to get satisfactory low-speed performance.

About 350 lb. of engine weight is added, with 6 to 10 in. of wheelbase, to obtain performance that is required not to exceed 10 to 20 per cent of the total driving time. The additional weight and length demand heavier frame, body, springs, axles and tires. A total added weight of 500 to 600 lb. and an increased fuel-consumption of 5 to 8 miles per gal. are the penalty.

Much smaller engines can be used if they are equipped with superchargers. As the mixture is forced into the cylinder by the supercharger, smaller and lighter valves that are less likely to overheat and to warp can be used, and the lift can be lower and more gradual. Consequently, the weight of the entire mechanism is reduced and, with it, the wear and the noise. Smaller manifolds and carbureters also are possible; in fact, these can be dimensioned for adequate gas-velocities that will give proper and economical carburetion at the lower

engine-speeds. At the higher engine-speeds, when excess power is required, the pressure of the supercharger takes care of the proper velocities, distribution and volumetric efficiency.

Results Obtained on a Dynamometer

As an example of what can be accomplished by the application of a supercharger, consider the following results that have been obtained on a dynamometer at 3000 r.p.m.:

156 hp. from a 360-cu. in. engine
115 hp. from a 240-cu. in. engine
85 hp. from a 175-cu. in. engine

A good passenger-car engine of 290-cu. in. piston-displacement developing 100 hp. at 3200 r.p.m. weighs, with all accessories, transmission and clutch, 1060 lb. It requires a length of 39 in. for bonnet space. At 1400 r.p.m., or 30 m.p.h., it develops 53 hp. and has a torque of 200 lb-ft. This engine can be replaced with one of 200-cu. in. piston-displacement that will deliver 92 hp. at 3200 r.p.m. with a supercharger. It weighs 690 lb., including all accessories, transmission, clutch and supercharger, and requires only 32 in. for bonnet space. At 1400 r.p.m., or 30 m.p.h., it develops 39 hp. without the supercharger and has a torque of 149 lb-ft. Curves for such an engine are shown in Fig. 1. This engine will handle the car very satisfactorily. With the supercharger operating at 1400 r.p.m., the horsepower is increased to 47 and the torque to 177 lb-ft. Comparing the two engines at 800 r.p.m., or 17 m.p.h., we find that the 290-cu. in. engine delivers 29.5 hp. and 195 lb-ft. of torque, and the 200-cu. in. engine delivers 22 hp. and 142 lb-ft. of torque without supercharging, and 25 hp. and 163 lb-ft. of torque with supercharging.

Consider also the other factors that enter into the construction of the car with the 200-cu. in. engine. The 7-in. shorter wheelbase will effect a saving in weight of at least 25 lb. per inch of length saved for frame, body, and propeller-shaft, or 175 lb. In springs, tires and brakes, another 100 lb. can be saved. To this 275 lb., add 370 lb. for reduced engine-weight, making a total of 645 lb.

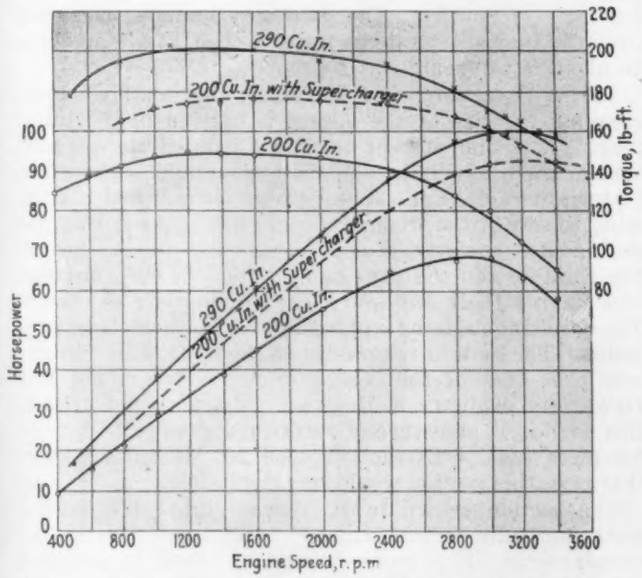

FIG. 1—TORQUE AND HORSEPOWER CURVES OF 290-CU. IN. ENGINE, AND OF 200-CU. IN. ENGINE WITH AND WITHOUT A SUPERCHARGER

The 200-Cu. In. Engine with a Supercharger Could Replace the 290-Cu. In. Engine in Ordinary Passenger-Car Service

TABLE 1—COMPARATIVE ACCELERATING ABILITY OF CARS EQUIPPED WITH A 290-CU. IN. ENGINE, AND WITH A 200-CU. IN. ENGINE, WITH AND WITHOUT A SUPERCHARGER

Engine Speed, R.P.M.	Car Speed, M.P.H.	290-Cu. In. Engine, Per Cent	200-Cu. In. Engine Without Supercharger, Per Cent	200-Cu. In. Engine With Supercharger, Per Cent
800	17	100	89	102
1,000	21	100	91	105
1,200	26	100	91	107
1,400	30	100	91	107
3,200	68	100	87	112

Comparative Accelerating Ability

Table 1 shows the comparative accelerating ability of two cars, one equipped with a 200-cu. in. and the other with a 290-cu. in. engine, assuming the ability of the latter car as 100 per cent. The figures are based on torque per pound of car weight, and show better performance for the supercharger-equipped car throughout the whole driving-range.

The economy under ordinary driving conditions will increase considerably, the 290-cu. in. engine giving about 16 miles per gal., and the 200-cu. in. engine, 20 to 22 miles per gal.

With the lighter and shorter chassis, the same body-space can be obtained, assuring seating comfort and leg-room. The riding-qualities will be as good if not better, because these do not depend so much on wheelbase as on unsprung weight and the position of the passengers relative to the springs and axles.

In my opinion the only practical application of a supercharger occurs when it can be engaged at will after the full-open position of the throttle is reached. If more power than the smaller engine will deliver at full-open throttle is needed for speed, acceleration, or hill-climbing, we then call upon our reserve and engage the compressor, with an immediate and thrilling increase of from 40 to 60 per cent in power.

Motorcoach and Motor-Truck Service

The advantages of supercharging for motorcoach service can be seen readily. Exclusive of maintenance cost and fuel economy, accelerating ability is the main factor in the earning capacity of the motorcoach in both urban and interurban service. Its performance must be equal to that of the passenger-car, for it is called upon to maintain the same average speeds. The motorcoach engine must give the necessary acceleration, as well as top speed, with gear ratios that will not cause excessive maintenance cost, and must give vibrationless operation. Experience in motorcoach service has shown that the engine speed should not exceed 1800 r.p.m., if satisfactory engine life is to be obtained. The severity of the service can be estimated when one considers that motorcoaches cover as much as 120,000 miles per year.

Engine sizes have of necessity been continuously increased to meet the requirements of this service. Whereas from 400 to 420-cu. in. engines were sufficient a few years ago, today 550-cu. in. engines are inadequate. The 420-cu. in. engine delivers about 80 hp. and the 550-cu. in. engine 110 hp. at 1800 r.p.m. As inertia forces increase in proportion to the product of the

square of the engine speed and the mass, and since mechanical failures cannot be tolerated because they reduce the earning capacity, smaller engines should be used.

The application of superchargers will allow the engine size to be reduced to 350 or 380 cu. in. Such an engine, with supercharger, will develop 115 hp. at 1800 r.p.m. On account of lighter reciprocating parts, the speed can be increased without injury to 2000 r.p.m., and 125 hp. can be obtained, which is more than that of the 550-cu. in. engine.

There is plenty of room on motorcoaches for blowers of larger type and higher speed. This will enable increased torque and horsepower to be obtained even at car speeds as low as 20 m.p.h. If the operator wishes to use a lower transmission-gear, much better acceleration can be obtained at low car-speeds than with the 550-cu. in. engine.

Advantages of Supercharging Motorcoaches

The advantages of using a supercharger in motorcoach service are manifold. The necessity for weight limitation can be complied with easily without sacrificing the mechanical proportions and ruggedness. This means that, for the same car speed and engine speed, the inertia forces and bearing loads will be smaller, the engine life longer, and the maintenance cost less. The fuel economy will be better on account of longer periods of operation with nearly full-open throttle when running without a supercharger.

With a supercharger, better acceleration will be obtained in city service and, in interurban work, top speeds will be reached more quickly. This results in greater earning ability. The preceding statements apply also to large motor-trucks, particularly in long-distance hauling.

Advantages of the Roots Blower

After a test of different types of supercharger on racing and passenger-cars, I believe that the positive-displacement type is best adapted to practical application. Our company has therefore selected the type known as the Roots blower, several views of which are shown in Fig. 2. The Roots blower has the following advantages:

(1) It can be built in sizes that can be accommodated under the hood.
(2) It can be operated at speeds that make it safe when put into the hands of the average owner.
(3) Its over-all efficiency is high, even in small sizes and throughout a wide range of speed.
(4) The rise of the air temperature through the blower is within such limits that no intercooler is required.
(5) It can be installed in front of the carbureter, thus avoiding the necessity for compressing a highly explosive mixture and the danger of backfiring and explosion. This eliminates the necessity for relief-valves.
(6) It allows a method of control by which it can be engaged at will, according to the power requirement; which, I believe, is the only method that will make practical and economical application possible.
(7) Much higher pressures can be obtained at comparatively low speed, bringing the range of the supercharging effect down into the lower engine-speeds and covering the entire driving-range.
(8) On account of its lower speed, extreme care in balancing is not necessary, and the gear problem in particular is simplified.
(9) The air is compressed inside a chamber in which no lubrication is required, thus eliminating any danger from gumming or excessive lubrication.
(10) Its application to medium and lower-priced automobiles is possible, because the initial cost of the device is low.
(11) Except for the length of the wings and the housing, practically the same parts can be utilized for a large range of sizes. We have designed one standard for engine displacements ranging from 100 to 400-cu. in. capacity.

Satisfactory and Efficient Wing-Section

Much study has been given to the question of the most satisfactory wing-section to use in Roots compressors. The first section usually considered is the mathematically correct cycloidal section shown in the upper left view in Fig. 3, in which the diameter of the generating-circle is one-quarter that of the pitch-circle. The area included between the housing bore and the side of the wing section represents the "bucket" in which the air is carried from the low-pressure to the higher-pressure side. The larger this area is, relative to the area of the wing section, the greater will be the volumetric efficiency.

One method of increasing this area is to use a larger generating-circle. In the upper right view in Fig. 3, the generating-circle has a diameter one-third that of the pitch-circle. The resulting epicycloid will mate with the corresponding hypocycloid on the other wing up to the point *a*, which is reached by the generating-point when the generating-circle has rolled one-eighth of the way round the pitch-circle. Beyond this point, the curves will not mate at tip and waist, hence the relief shown. This section is substantially that recommended for blowers by the National Advisory Committee for Aeronautics. The gain in volumetric efficiency over the type shown at the upper left of Fig. 3 amounts to about 7 per cent.

In the lower left view in Fig. 3, this method of increasing the size of the bucket is carried to the limit, making the diameter of the generating-circle one-half that of the pitch-circle, and the hypocycloid is therefore a straight radial line. These proportions would cut the wing in two, if the whole line were used. As in the preceding case, however, the curves would not mate beyond the point *a*, and the gaps can be filled in with circular arcs having their centers on the pitch-circle, as shown. The resulting sections will mate with mathematical precision. The gain in volumetric efficiency is nearly 18 per cent over that of the design shown in the upper left view. For ordinary methods of construction, however, this section is structurally weak in the waist. For the one-piece steel construction used in Mercedes superchargers, this section would be permissible.

The section shown in the lower right view is not mathematically correct, since it is an approximation of circular arcs. It is more efficient by about 13 per cent than the section shown in the upper left view. It is substantially the same section as that used in the latest 2-liter Mercedes superchargers. We have adopted this section, not only because of its relatively good volumetric efficiency and adequate waist strength, but because the

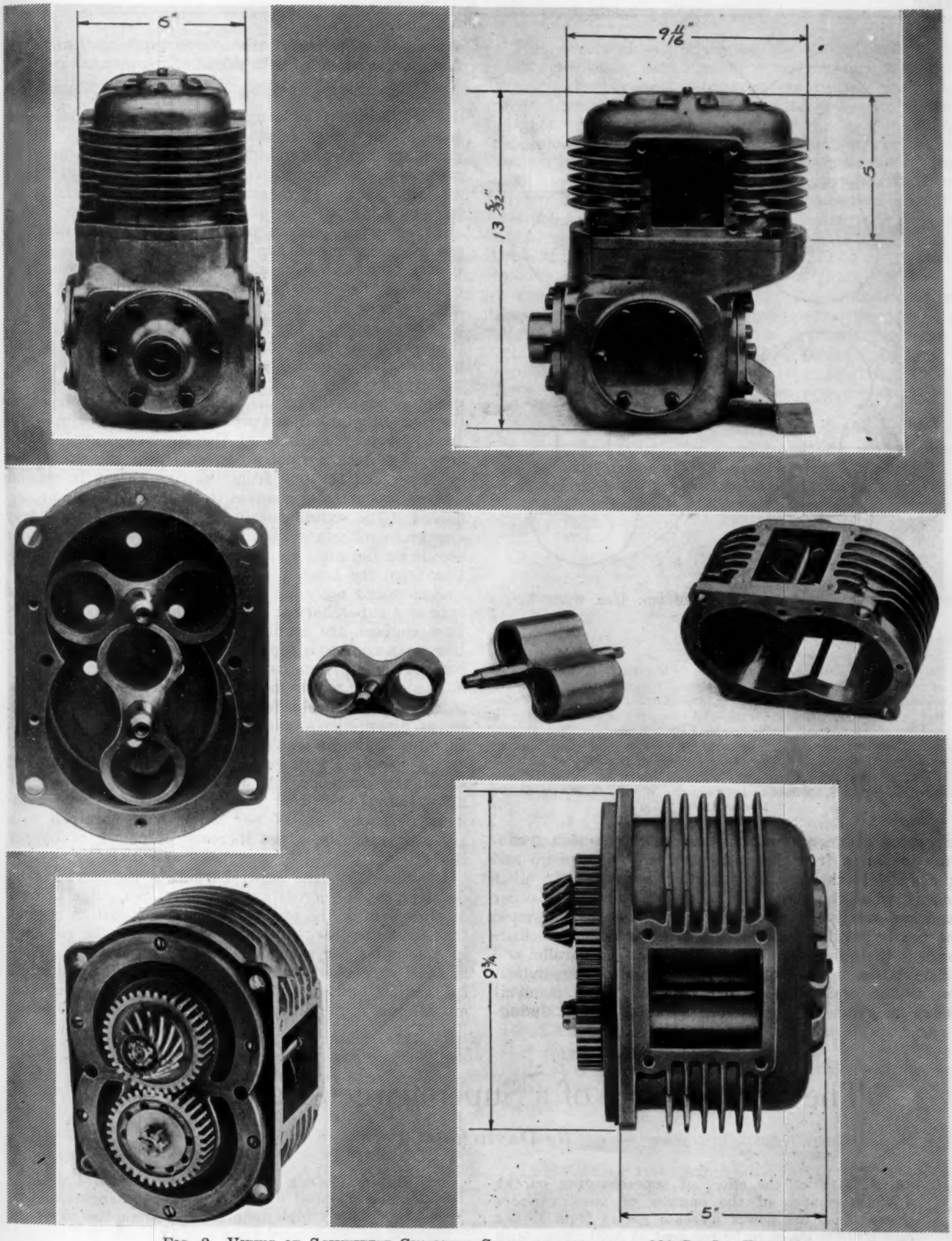

FIG. 2—VIEWS OF SCHWITZER-CUMMINS SUPERCHARGER FOR A 200-CU. IN. ENGINE

A Front View of the Supercharger, with the Driving Mechanism, Is Shown at the Upper Left; a Side View, at the Upper Right; the Inside of the Housing with the Wings in Place, at the Central Left; the Wings Removed from the Housing, at the Central Right; the Driving-Gears and Semicircular Headers, at the Lower Left; and a View with Driving Mechanism Removed at the Lower Right

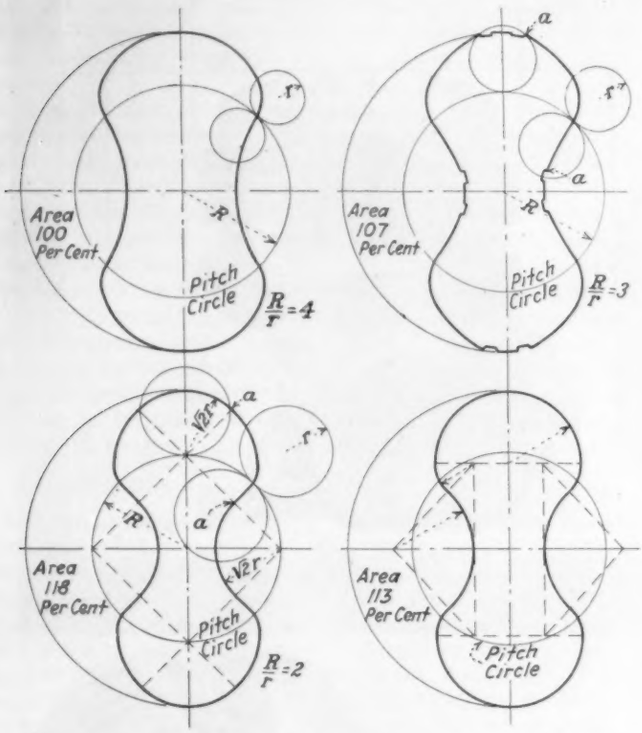

FIG. 3—STUDY OF WING SECTIONS FOR USE WITH ROOTS COMPRESSORS

The Mathematically Correct Cycloidal Section Is Shown at the Upper Left; a Method of Increasing the Area between the Housing Bore and the Side of the Wing Section, by Using a Larger Generating-Circle, at the Upper Right; a Method of Increasing the Size of the Bucket, the Pitch-Circle Being Twice That of the Generating-Circle and the Hypocycloid Being a Straight Radial Line, at the Lower Left. A Section, Not Mathematically Correct but More Efficient by 13 Per Cent than That at the Upper Left, Which Has Been Adopted Because of Its Relatively Good Volumetric Efficiency, Adequate Waist-Strength, and Better Distributed Clearance between the Wings, Is Shown at the Lower Right

clearance between a pair of wings of this section gradually increases from the minimum between the tip and the waist to the maximum at the shoulders. In other words, when the wings are perpendicular to each other and any relative motion between the two wings would be nearly parallel to the proximate surfaces, the clearance is the minimum. When the wings are parallel and any relative motion between them would be perpendicular to the proximate surfaces, the clearance is about 0.085 in. greater. Thus, more backlash in the timing-gears can be tolerated than for a mathematically perfect section running with uniform clearance.

CARBURETER AND FUEL-FEED CHANGES NEEDED

For operation in connection with a supercharger, some changes must be made in the carbureter. All the parts through which air could escape from the inlet passage to the atmosphere must be rendered practically airtight. Hence it generally is necessary to fit a detachable cap over the end of the float-valve-stem guide, and the upper portion of the float-chamber must be placed in communication with the delivery side of the blower by means of a small pipe. When the pressure is equalized, the effect of varying pressure is eliminated, and the float and nozzle operate exactly the same as on a normal engine. The fuel must, of course, be fed to the carbureter under pressure, which is easily accomplished by a conventional fuel-pump.

Mercedes uses a regular vacuum-tank having a capacity of more than 2 gal. Engaging the supercharger converts this tank into a pressure system through a pipe from the pressure side of the supercharger. At the same time, the normal air-intake from the carbureter is closed and the one from the compressor is opened.

Few fundamental changes in the engine itself are required. The cylinder-walls in most cases are heavy enough to withstand the higher pressures. The pistons should be designed to assure satisfactory heat conduction from the head.

A correctly designed normal cooling-system will take care of a supercharged engine. The bearings of American engines are ample, being larger than those of European engines equipped with superchargers and having the same piston-displacements.

The power requirement for supercharging at 7-lb. per sq. in. pressure-difference is about 4 hp. per 100 cu. in. of piston-displacement at 3000-r.p.m. engine-speed. In return for this we receive a net increase in percentage of power 1.8 times the increase in percentage of volumetric efficiency. At 3000 r.p.m., few engines have more than 70-per cent volumetric efficiency. A volumetric efficiency of 100 per cent can be obtained with supercharging, or a net increase in power of 55 per cent.

I believe that the supercharger is the next logical development in increasing the output per cubic inch of displacement of the present internal-combustion engine, that the supercharged engine will increase the economy in road-miles per gallon of fuel, and that the development of supercharger application will lead to a successful, flexible and economical two-cycle engine, which, in my opinion, is the ultimate engine for automotive work.

The Performance of a Supercharged Passenger-Car

By DAVID GREGG[1]

A STUDY of the effect of supercharging on the performance of the engines of passenger-cars showed that the power increase varied from 35 per cent at 1000 r.p.m. to 59 per cent at 3000 r.p.m., with a maximum supercharging pressure of only 6.5 lb. per sq. in. In acceleration tests made at the General Motors Proving Ground of two cars of similar model, one equipped with a supercharged engine and the other with a high-compression engine, the supercharged car accelerated from 5 to 25 m.p.h. in 5 sec.; the unsupercharged car, in 10 sec. From 15 to 50 m.p.h. the supercharged car accelerated in 12.7 sec.; the unsupercharged car, in 21.0 sec. On an 11-per cent grade up which the cars were started at 10

[1] M.S.A.E.—Research engineer, A. C. Spark Plug Co., Flint, Mich.

m.p.h., the speed of the supercharged car was 40 m.p.h. at the top; that of the unsupercharged car was 18 m.p.h. These and other results of the tests are portrayed by curves.

A SUPERCHARGER developed in our laboratories proved reasonably efficient, quiet and durable, and our interest centered on learning how it would affect the performance of a standard passenger-car. Our experience with the application of superchargers to various types of engine indicated that the best results on passenger-cars called for a reasonable amount of pressure at low engine-speeds, a requirement that virtually eliminated the centrifugal type of supercharger and led to the development of the positive-vane type of simple construction shown in the left portion of Fig. 1.

The problem of applying this supercharger to an engine presented numerous difficulties, particularly in obtaining a suitable drive, for no engine already in production had provision for a power take-off that required more than 1 or 2 hp. As it had a built-in chain-drive for the magneto, the export model of a six-cylinder 180-cu. in. engine was selected for these tests. By placing a sprocket on the magneto drive, the supercharger could be located above the inlet ports and be driven by chain; and the ratio of its speed to that of the engine could be readily changed. This was not a quiet drive, but it answered our requirements because we were more interested in securing data and results without great expense than in designing a drive such as might be used on a supercharged car in production. This arrangement is shown at the right in Fig. 1.

Arrangement of First Test Set-Up

Two methods of supercharging the engine were tested. Each had certain advantages and disadvantages. In the first installation, air under pressure was blown into the carbureter. The supercharger ports were arranged for the hydraulic cycle, with no compression in the supercharger itself, the pressure being built up by back-flow, as in a Roots blower. A three-way valve allowed the air from the supercharger to be led into the carbureter or wasted into the atmosphere. The control was arranged so that, when the carbureter throttle was wide open, a further movement of the throttle lever gradually closed the valve between the supercharger and the carbureter air-intake, until the maximum supercharging pressure was reached.

Variations in the foregoing method were tested, but the first set-up gave as good results as any. As the pressure of the intake air in the carbureter varied above atmospheric, it was necessary to use an internally balanced carbureter having a sealed float-chamber and to supply fuel under a constant differential pressure. Ordinarily, this requires a complicated fuel system with a balanced fuel-relief valve, as used in the Air Service, but on this particular installation a very simple system was developed that employed an A.C. fuel-pump and a line leading from the pressure side of the supercharger to the under side of the fabric diaphragm. By these means the air pressure in the float-chamber was exactly balanced by similar air-pressure on the under side of the fuel-pump diaphragm, which acted with the discharge-spring so that the fuel was always under a constant differential-head at the float-valve.

This system of supercharging had two important advantages. Under part throttle, when pressure from the supercharger was not needed, as the air was not compressed, the only power required to drive the supercharger was that needed to overcome the friction in the supercharger. A saving of several horsepower under ordinary driving-conditions was therefore made. The second advantage was that the supercharger could be located at any place where a drive could be obtained. It was not necessary that it should be located with respect to the position of the carbureter or of the inlet ports; it could be driven from the front end of the crankshaft, making a neat and simple installation.

The difficulties were of a minor nature and could be removed with a little experimental work. There was a slight tendency for the oil in the supercharger to become gummed when only air passed through the supercharger. The hydraulic cycle necessary for this installation decreases in efficiency as the pressure increases, but the actual loss as compared with that of a compressor working on the adiabatic cycle is negligible for the pressures used. The greater difficulty is in balancing the carbureter. On the first set-up, the carbureter was placed in a sealed box subjected to supercharger pressure. This was satisfactory up to about 2 lb. per sq. in. above atmospheric pressure. Then an internally balanced carbureter was obtained that gave good results and power characteristics up to 4 lb. per sq. in. above atmospheric pressure, but operated badly above that pressure and was very difficult to adjust. As we could secure no cooperation from the makers of the carbureter we were using, we temporarily dropped this method of supercharging.

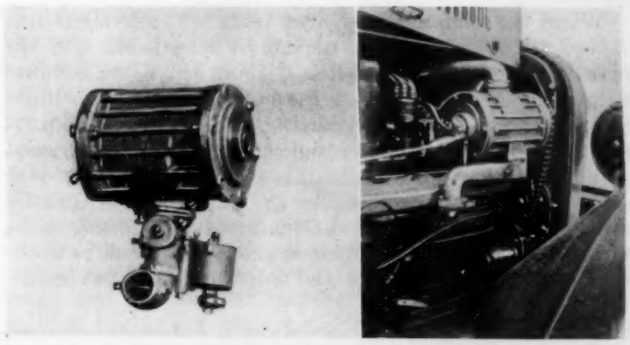

Fig. 1—Positive-Vane Type of Supercharger Used

The Carbureter Attached to the Supercharger as Shown at the Left Was Used in Obtaining Characteristic Curves of the Supercharger Alone. The View at the Right Shows the Method of Installing the Supercharger on the Engine, and the Chain Drive. The Carbureter Is on the Far Side of the Engine. An Inverted Carbureter Directly on Top of the Supercharger Probably Would Have Given Better Results

Set-Up with Standard Carbureter

In the second arrangement, the carbureter was located at the intake of the supercharger and the supercharger outlet was connected directly to the inlet manifold as shown at the right in Fig. 1. The carbureter throttle was the only control needed. We did not use a blow-off valve for preventing damage from backfiring, and had no trouble on that account, although the blow-off valve is used on many supercharged foreign cars and appar-

ently is found to be necessary. The supercharger was located above the inlet ports to prevent loading under idling conditions. With this arrangement, there was no trouble with carburetion; the fuel mixture passing through the supercharger seemed to aid in distributing the oil to all the working parts and lowered the operating temperature of the supercharger, though the final temperature of the mixture was the same as that of the first system.

With the exception of the carbureter trouble noted previously, there was little difference in the power obtained in the two systems. Each gave about the same power-increase and each showed good accelerating characteristics; but, because of the difficulty of securing a suitable balanced carbureter, the greater part of the testing was done with a standard carbureter at the intake of the supercharger.

Test Procedure

The engine on which the tests were made was standard in every way and, with the exception of substituting the maker's latest type of valves at the beginning of the tests and removing the hot-spot in the manifold, no changes were made. The engine was first run for some time on an electric dynamometer, and a curve of unsupercharged horsepower, as shown in Fig. 2, was obtained.

When the supercharger was installed, ethyl gasoline mixed with 20 per cent of benzol was used, and the spark was retarded until it had about the same advance as on the same type of engine equipped with the high-compression head that was being sold as optional equipment. Preignition was encountered at first. On measuring the manifold temperatures, the temperature rise caused by the compression in the supercharger and by a permanent hot-spot in the manifold was found to be excessive. Trouble from this source was almost entirely eliminated by separating the inlet and exhaust manifolds. Fuel consumption was not measured, but road tests showed it to be 15 miles per gal. at an average speed of 50 m.p.h., a very reasonable figure for the car used.

The power required to drive the supercharger increases rapidly with speed, as both the volume and the pressure are increasing, as shown in Fig. 3. The minimum power at idling speeds was 0.5 hp.; the full-throttle power at 3000 r.p.m. was 10.5 hp. These curves are shown in Fig. 4.

The characteristic curves give a good idea of the results gained by supercharging. The power increase varied from 35 per cent at 1000 r.p.m. to 59 per cent at 3000 r.p.m., with a maximum supercharging-pressure of only 6.5 lb. per sq. in., as shown in Fig. 5. Curves showing manifold temperatures, Fig. 6, are also of interest. The difference between the upper and the lower curves shows the temperature rise due to the compression in the supercharger. The difference between the middle curve and the upper curve gives the decrease in the mixture temperature due to the vaporization of the fuel.

Road Tests and Performance

The supercharged engine was installed in a two-door sedan and, after several minor road adjustments were made, was taken to the General Motors Proving Ground and tested beside a car of similar model equipped with a high-compression engine using ethyl gasoline. On accelerations from 5 to 25 m.p.h., the supercharged car averaged 5 sec. flat; the unsupercharged car, 10 sec. From 15 to 50 m.p.h. the supercharged car accelerated in 12.7 sec.; the unsupercharged car in 21.0 sec. In each case three persons were in the car. In the hill-climbs, which gave the best visual proof of the superiority of the supercharged car, the cars started side by side. Both were started at 10 m.p.h. and, at the zero mark, the throttles of both were opened wide. On the

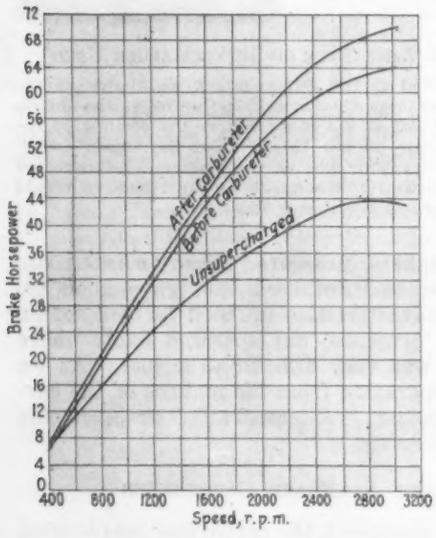

FIG. 2—CURVES SHOWING THE RESULTS OF THE TEST OF AN A. C. SUPERCHARGER

The Supercharger Was Mounted on a Six-Cylinder Four-Cycle Engine of 180-Cu. In. Capacity, the Speed at Which It Was Driven Was 1.28 Times That at Which the Engine Was Running

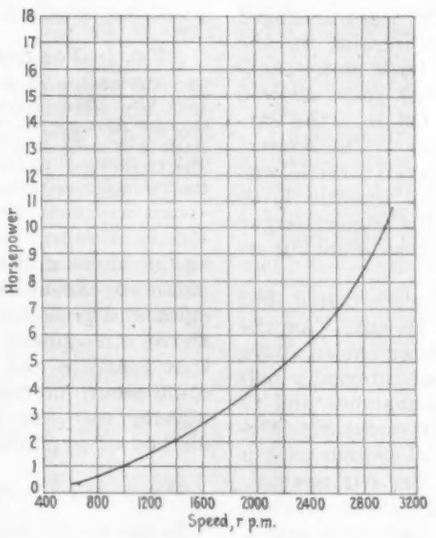

FIG. 3—POWER REQUIRED BY THE SUPERCHARGER

The Supercharger Speed Was 1.28 Times the Engine Speed. The Power Required To Drive the Supercharger Increases Rapidly with Increase of Speed, as Both the Volume and the Pressure Are Increasing

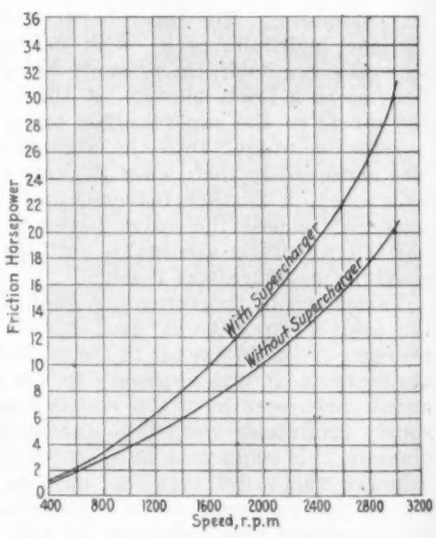

FIG. 4—CURVES OF FRICTION HORSEPOWER, WITH AND WITHOUT AN A. C. SUPERCHARGER

The Supercharger Speed Was 1.28 Times the Engine Speed. The Minimum Power at Idling Speeds Was 0.5 Hp.; Full-Throttle Power at 3000 R.P.M. Was 10.5 Hp.

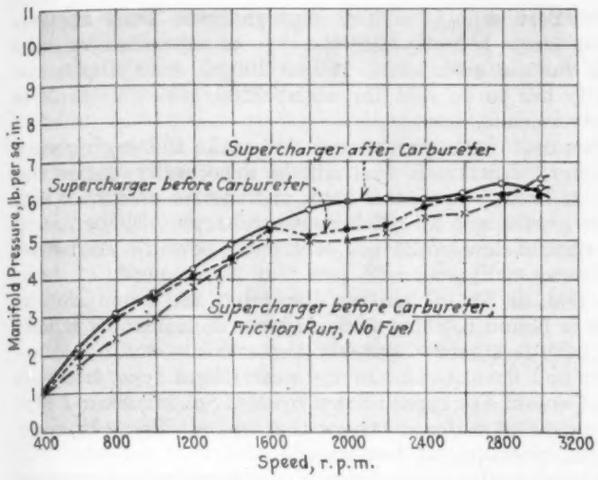
Manifold Pressure, lb. per sq. in.
Speed, r.p.m.
Supercharger after Carbureter
Supercharger before Carbureter
Supercharger before Carbureter; Friction Run, No Fuel

FIG. 5—CHARACTERISTIC CURVES SHOWING MANIFOLD PRESSURES AT VARIOUS ENGINE-SPEEDS

The Speed of the Supercharger Was 1.28 Times the Engine Speed. The Power Increase Varied from 35 Per Cent at 1000 R.P.M. to 59 Per Cent at 3000 R.P.M. It Should Be Noted That the Maximum Pressure Resulting from Supercharging Was Only 6.5 Lb. per Sq. In.

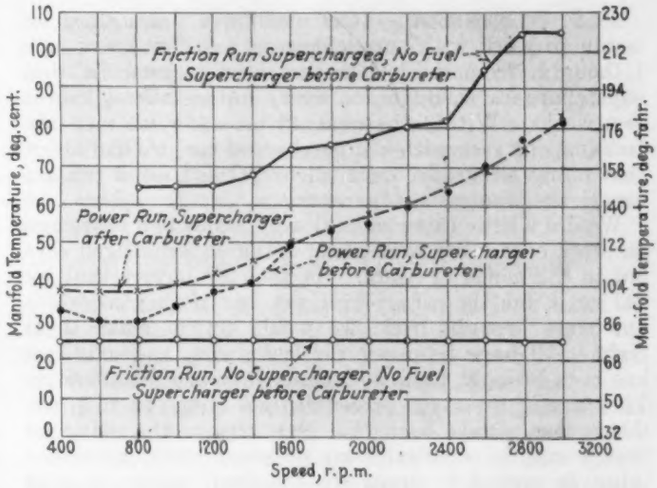
Manifold Temperature, deg. cent.
Manifold Temperature, deg. fahr.
Speed, r.p.m.
Friction Run Supercharged, No Fuel Supercharger before Carbureter
Power Run, Supercharger after Carbureter
Power Run, Supercharger before Carbureter
Friction Run, No Supercharger, No Fuel Supercharger before Carbureter

FIG. 6—CURVES SHOWING MANIFOLD TEMPERATURES AT VARIOUS ENGINE-SPEEDS

The Speed of the Supercharger Was 1.28 Times the Engine Speed. The Difference between the Upper and the Lower Curves Shows the Temperature Rise Due to the Compression in the Supercharger. The Difference between the Middle and Upper Curves Gives Decrease in Mixture Temperature Due to Vaporization of the Fuel

7-per cent grade, the supercharged car was running at 50 m.p.h. at the flat turn in the roadway and slowed down for the remainder of the climb, as part of the track was covered with ice. The unsupercharged car reached the 1400-ft. mark at 20 m.p.h. On the 11-per cent grade, the cars were also started at 10 m.p.h., and the supercharged car reached the top at a speed of 40 m.p.h., the unsupercharged car at 18 m.p.h. The gain in maximum speed was not so great as might be expected from first consideration; but, as the engine speed was greater than that of maximum horsepower and as the power required to drive the car was increasing rapidly, the results are reasonable. A speed of 69 m.p.h. was reached by the supercharged car, and 64 m.p.h. by the unsupercharged car.

It is difficult to portray by mere figures the sensation of power and fleetness obtained while driving a supercharged car. At road speeds from 35 to 50 m.p.h., the car was a delight to drive, accelerating past other cars with ease. At all speeds up to the maximum there was no laboring of the engine; power always seemed to be in reserve. Starting and accelerating in second gear provided a get-away that left other cars far behind. The car ran smoothly in high gear at 10 m.p.h., and further experiments with carbureters and manifolds undoubtedly would reduce this figure. The chain drive was noisy, but the supercharger itself was reasonably quiet and had no objectionable note.

It is useless to draw conclusions from a single test. The facts only are therefore offered in the hope that they may prove of interest to others engaged in similar lines of research.

THE DISCUSSION

ONLY the turbo or centrifugal type of supercharger would be successful on passenger-cars, according to one discusser, because some device is needed to break up the fuel rather than to supercharge the engine. Automobiles could run faster if they could get more fuel, and a stock-car engine equipped with a supercharger should develop 25 per cent more power than if unsupercharged. A two-cycle engine equipped with a supercharger will develop, at low throttle, about three times as much horsepower per pound of fuel as a conventional four-cycle engine.

Superchargers on airplane engines operate under ideal conditions, according to another speaker, because the density of the air at great altitudes is less than that at sea-level and the temperature is lower. The turbo type seems best for airplanes because the kinetic energy of the exhaust gases can be utilized, but it is difficult to find a suitable material for constructing the turbine buckets, which operate in gases of very high temperature. To obtain the most satisfactory operation, the engine must be designed to meet the requirements of the supercharger.

A centrifugal supercharger having a low gear-ratio maintains the mean effective pressure of the engine constant independently of the engine speed, points out another member, who states that a water-cooled engine rated nominally at 800 hp. is being designed which will develop 1000 hp., it is hoped, when the mean effective pressure is maintained constant at high speeds. The possibility of reducing the weight of aircraft engines by using a two-stroke cycle and supercharging is being studied.

The advantages and disadvantages of suction-type and pressure-type superchargers are discussed, and some research work is mentioned that showed that the use of the centrifugal-type supercharger on a passenger-car engine increased the horsepower 18 or 20 per cent at 3000 r.p.m. The demand of the public for continually increasing the power of cars has caused too large and too heavy engines to be used, it is said, and superchargers must eventually be adopted.

One investigator terms the supercharger a pressure-restorer, as its function is to maintain the inlet pressure.

F. S. DUESENBERG[1]:—It is about five years since we began to work with superchargers. A few years ago, I thought, from the letters that used to come in, that superchargers would be on every automobile within a few weeks. Within the next 48 hr. after we won the Indianapolis race with a supercharged car, we had about that many telegrams from all over the United States; everybody wanted a supercharger.

We did a little experimental work about two years ago on stock cars. We have about seven supercharged cars out in the hands of users. We told the buyers that we did not think the cars were right, but if they were not and were brought back, we would try to make them right. All have been out for two years, and only one has been brought back, so I think they are satisfactory. They are of the turbo or centrifugal type. In fact, my theory has always been that this type is the only one that would be successful on passenger-cars, as something is needed to break up the fuel rather than to supercharge the engine. Most of the cars today have plenty of compression at speeds of 10, 15 or 20 m.p.h. If they had much more they would knock. Most cars that go 40, 50 or 60 m.p.h. could go much faster if they could get more fuel. The turbo type of supercharger breaks up the fuel considerably; in fact, I think that during the first two years we used superchargers we got more power, not because of the supercharging, but because of the better mixture in the cylinder.

After the Indianapolis race in the year Joe Boyer finished the supercharged car and drove part of the race, when the valves were taken out, the exhaust valves had bright seats, which proved that the engine had been running very cool and was very efficient; but as time went on, I felt that possibly it is wrong to have a supercharger directly connected with the engine and running continuously, unless it is of the turbo type. I feel that it is not right, with the present carbureters, to place the carbureter between the supercharger and the engine. We made experiments and had a great deal of trouble; we could not get proper carburetion. Perhaps that trouble has been overcome. The Mercedes car seems to have been successful. The locating of the supercharger between the carbureter and the engine probably avoids some of the trouble, but it also seems probable that it might cause other trouble on account of having larger areas exposed to the mixture and more accumulation and condensation of fuel at low speeds.

For the last year or two we have not tried to put superchargers on new passenger-cars. We do not expect to supercharge them now, as we have taken other means of getting more mixture into the cylinders at the higher speeds. We believe we are doing about as well as we could with a supercharger. Without question, the efficiency of nearly all stock cars as they are built now could be increased substantially by the use of a supercharger of some kind. Hardly a day passes that I do not get a letter from some person in a hilly locality or from some one who wants more speed on level roads and wishes to know about superchargers for various cars of popular make; so some of these cars probably are not so fast as the owners would like them to be. I usually tell them that the supercharger costs considerably more than their cars did originally, and that they had better keep the car as it is. A man in New York who is selling superchargers built in Germany wrote recently that the type of supercharger suitable for automobiles of 150 to 200-cu. in. cylinder capacity are to be sold for about $200, which I think is fairly reasonable.

The use of a supercharger will make the engine very efficient. Antiknock fuel will be a necessity unless the fuel is broken up better than ordinarily. With an efficient engine and an efficient supercharger, the ordinary car should develop 25 per cent more power. That does not necessarily mean 25 per cent more speed.

I feel, as Mr. Schwitzer does, that the two-cycle engine is bound to come some day, we do not know when; but with it a good supercharger certainly will be necessary, and it cannot be of the centrifugal type, but will be of one of the types shown by Mr. Schwitzer and Mr. Gregg, or of a dozen others that are similar. It must deliver pressure at low speeds.

At Valparaiso, Ind., I saw a single-cylinder two-cycle engine operate very satisfactorily at 200 r.p.m., it being the first two-cycle engine I have ever seen operate at this low speed. I think that this engine, in combination with a good supercharger, would be very satisfactory. Another point about this engine that I think would be very satisfactory is that it has constant compression. At low throttle it will develop about three times as much horsepower per pound of fuel as the four-cycle engine that we have today. This would mean that, instead of getting 15 or 18 miles per gal. with an ordinary car, we probably would get 40 miles per gal. I think a great many people are looking for that.

SUPERCHARGING OF AIRCRAFT ENGINES

A. L. BERGER[2]:—Superchargers for aircraft engines are similar to those employed in automobile engines and provide a means either of obtaining additional horsepower or of maintaining a given horsepower at various altitudes. In aircraft-engine work, however, the conditions for supercharging are ideal, because the engines operate in an air density that is considerably less than that at sea-level; they also secure the benefits of the low temperatures at the higher altitudes. This is especially beneficial insofar as turbo supercharger operation and engine temperatures are concerned.

At the time of the inception of the supercharger for aircraft engines, nearly all known types of compressor were considered, but the turbo type seemed to be best adapted to aircraft, probably because the kinetic energy available in the exhaust gases could be utilized, and the necessity for taking power from the crankshaft for operating the supercharger could be avoided.

Some idea of the results achieved from supercharging aircraft engines may be obtained when one considers that a 400-hp. engine at 20,000-ft. altitude develops approximately only 195 hp. and that, by supercharging the engine to sea-level pressure at that altitude, practically normal sea-level horsepower is again made available.

The hardest problem encountered in the development of the turbo supercharger was that of securing a satisfactory metal for the turbine buckets. When one considers that the turbines operate in red-hot exhaust-gases, the temperatures of which are from 1200 to 1500 deg. fahr., he can realize the difficulties of the problem. After six or seven years we finally developed a metal for the turbine buckets that has proved very successful. We have standardized on turbo superchargers for

[1] M.S.A.E.—Vice-president, in charge of engineering, Duesenberg, Inc., Indianapolis.

[2] In charge of supercharger department, Wright Field, Dayton, Ohio.

aircraft work, but that does not close the field to other types of supercharger. We are considering doing some work with vane-type blowers, some designs of which seem to offer possibilities.

As an illustration of the performance of an airplane equipped with a supercharger, I might cite the present Air Corps standard pursuit-airplane, which, when equipped with an unsupercharged engine, has a time of climb to 20,000 ft. of approximately 26 min.; but, when the engine is equipped with a supercharger, the time of climb to the same altitude has been reduced to less than 12 min. It is likely that in the near future altitudes of 20,000 ft. will be reached in 7 or 8 min.

After considerable experimenting with the turbo-type supercharger, it was believed possible to connect a gear-driven centrifugal supercharger directly to the rear of the engine. There was, however, a rather grave question whether a satisfactory connection could be made, because of the oscillation of the crankshaft. Later developments have shown our skepticism to be well founded.

I cannot say that we have yet overcome the drive problem. A great many types of couplings and drives have been tested, but none has proved successful. It is probable, however, that this difficulty can be largely overcome by building the supercharger directly into the engine. Some work has also been done with the Roots-type supercharger, as developed by the National Advisory Committee for Aeronautics. The tests of this type to date, however, have not been conclusive, as a number of mechanical failures have been encountered. In general, mechanical difficulties have been the cause of the greatest trouble, irrespective of the type of supercharger. These are probably more serious than those of superchargers used with automobile engines, because superchargers for aircraft engines must be constructed of the very lightest material. Superchargers used with aircraft engines of 400 to 500 hp. weigh less than 100 lb. The light construction increases considerably the possibility of mechanical trouble.

With regard to supercharger air-discharge temperature, the final temperatures should be approximately the same for the same compression-pressures, whether the supercharger is a turbo, geared centrifugal, rotary or vane-type compressor. That of the centrifugal type probably is slightly less than that of the others at the higher operating speeds.

Intercoolers are essential for cooling the air, especially when high mean effective engine-pressures and high supercharger-pressures are maintained. At present, this is not so noticeable in automobile-engine use because lower compression-pressures are used.

Another thing that we had to deal with was the psychological effect of putting a supercharger on an airplane engine. Pilots in the Air Corps are like the rest of us; they do not like high altitudes and extremely low temperatures. But we have gone through the educational period, and pilots, after 10 years' work, have actually taken to liking superchargers.

To make a real success of superchargers with automobile engines, the basic facts of the problem must be observed, in that the engine must be designed and built for the supercharger. If it is not, the result will be merely a car with an engine that will give only mediocre performance. In my opinion, the best field for superchargers at present is on two-cycle and Diesel engines. If superchargers were installed on present cars, it is doubtful whether more than a limited number of people would obtain the results they expect.

The cost of superchargers at present is prohibitive, and for some time to come it probably will be a great deal cheaper merely to increase the displacement of the engines.

Maintenance of Sea-Level Conditions

N. N. Tilley[3]:—All we are trying to do is to maintain sea-level conditions up to the altitude for which the supercharger is rated. The principal change we have made has been to use a better fuel with the supercharged engines. We have used superchargers, in the form that we call rotary induction, to maintain the brake mean effective pressure up to much higher speeds than could be maintained without the supercharger. For instance, in most aviation engines the maximum mean effective pressure occurs at about 1800 to 2000 r.p.m.; in radial engines it occurs at a considerably lower speed. By putting on a centrifugal supercharger having a low gear-ratio, the mean effective pressure can be maintained constant practically independent of the engine speed. The engines do not have a power peak; it is merely a question how fast it is safe to run them. When a propeller is on the engine, the power of any given airplane in level flight is definitely limited.

All large radial engines have built-in centrifugal superchargers designed to keep approximately sea-level pressure in the inlet manifolds regardless of the speed. The supercharger is a wonderful spray-device, which maintains a uniform mixture in all the cylinders and causes the engine to operate very smoothly. It is probable that it will be incorporated in most of the military radial engines.

We are now conducting an experiment on a large water-cooled engine with a view to keeping the mean effective pressure constant at higher speeds. An engine of a type normally developing less than 800 hp. is now under construction that we hope to make develop 1000 hp. merely by maintaining at a higher speed the mean effective pressure it develops at a lower speed. Preliminary running indicates that this will be attained but that it may be necessary to use a better antiknock fuel than domestic aviation gasoline.

In the future we probably shall have a two-cycle engine using a displacement-type supercharger for aircraft. The possibility of a lighter engine comes from the fact that a much smaller compressor can be obtained in the form of a rotary compressor than in that of a piston compressor. But some form of mechanical metering-device probably will have to be used to distribute the fuel properly in a two-cycle engine, and also to prevent waste of fuel.

Air-Corps Use of Carbureters

Opie Chenoweth[4]:—At the Materiel Division of the Air Corps, we have standardized more or less on two types of carbureter: the suction-type and the pressure-type. The terms, of course, merely tell the location of the carbureter relative to the supercharger. F. G. Shoemaker, of the Materiel Division, who did a great deal of work on superchargers, outlined the relative advantages and disadvantages of the two locations, and I have taken the liberty to copy some of his notes.

[3] S.M.S.A.E.—Associate mechanical engineer, materiel division, Army Air Corps, Wright Field, Dayton, Ohio.

[4] Jun. S.A.E.—Assistant mechanical engineer, materiel division, Army Air Corps, Wright Field, Dayton, Ohio.

The chief advantage of a suction-type carbureter, as we know it, is complete control of the engine and supercharger with one valve. It is also possible to use a gravity fuel-system. We find that in centrifugal superchargers the efficiency increases because of a lowering of the mixture temperature by the absorption of heat by vaporization of the fuel. Its greatest disadvantages are a large amount of combustible charge in the supercharger and manifold that many times causes difficulty because of backfiring or preignition, and the formation of ice in the carbureter. The second disadvantage is perhaps not of great importance in automobile work, but it is to us. In the suction type, formation of ice in the carbureter may increase the restriction, or the ice may become loose and go into the high-speed impeller, causing chipping. This is particularly noticeable when using benzol. A third disadvantage is the large area of the inlet manifold and of the supercharger itself that must be wetted by the accelerating charge.

The outstanding advantages of the pressure-type carbureter are the small charge of fuel and air in the inlet manifold, which causes very little injury in case of backfiring, and the lack of difficulty with ice formation, because the temperature rise in the supercharger makes the air temperature high enough so that ice will not form. Under these conditions the maximum temperature difference is obtained for intercooling, which is important with high compression-ratios, because of the great difference in temperature between the air inside and that outside the intercooler.

The disadvantages are the necessity for a pressure fuel-feed to the carbureter and for a separate control-valve for the supercharger, unless a type is used such as the carbureter used by Mr. Schwitzer. An additional difficulty is that the carbureter must be specially built, that is, tightly sealed throughout and internally vented, Great care must be taken to use packing around the throttle and mixture-control shafts because, without it, as the altitude increases the pressure difference will force a combustible charge out around the throttle shafts and impair the action of the mixture control.

My experience with the breaking-up of the fuel by the impeller does not agree entirely with Mr. Duesenberg's. About two years ago we had a Curtis D-12 engine with a 7500-r.p.m. centrifugal supercharger and suction-type carbureters in the altitude chamber of the Bureau of Standards, and we reduced the pressure and the temperature of the air to the carbureter simultaneously. We have made several runs in the dynamometer laboratories, and the distribution, we thought was almost perfect on the ground, the flames from the various cylinders being absolutely uniform. We were using six-cylinder gallery-type manifolds. When we went up to altitudes where the mixture temperature was reduced because of the lower inlet-air temperature, we found that No. 1 cylinder gave a great deal of trouble on the left bank. We took the spark-plugs out and found them badly carbonized. We found that this was due entirely to the inferior distribution resulting from the lower mixture-temperatures. The actual speed of the supercharger was the same as it had been on the ground, hence the mechanical atomization was the same; but the temperature of the mixture from the supercharger was so much lower that difficulty resulted. Substitution of standard three-cylinder-type manifolds for the gallery type increased the output by 50 b.hp. at 25,000 ft., showing that distribution remains an important problem, even with supercharged engines.

Centrifugal-Supercharger Research

President W. G. Wall[5]:—To get more power out of automobile engines, especially those used in passenger-cars, it has been my opinion for some time that the next step would be the use of superchargers. This has been borne out by the experience with racing-car engines and with airplane engines for high-altitude work. I know of no other practical way to get high volumetric-efficiency at high speeds.

There are several different kinds and types of supercharger: blower, centrifugal, vane, and piston types. Each has advantages and disadvantages. It is a question whether we have yet hit upon the one that will eventually be used. The centrifugal and the vane types can best be applied to a passenger-car engine by using a very small engine having a high compression-ratio, then attaching the supercharger to get high efficiency, cutting in the supercharger when it is desired for hill-climbing, acceleration and high-speed work. This would give a large expansion-ratio, especially at the normal speeds, which would mean good economy. Efficiency, of course, increases with the expansion ratio and not necessarily with the compression ratio, whereas, all other things being equal, the power developed is directly proportional to the weight of the charge that is burned per unit of time.

Research work that I conducted for the Marmon Motor Car Co. was with the centrifugal-type supercharger. This research was suspended because of the pressure of other work. The supercharger on a certain passenger-car engine at about 3000 r.p.m. gave an increase in horsepower of from 18 to 20 per cent. I think we see how we could get possibly 30 per cent. There was considerable friction in the method of driving the supercharger.

We first tried the turbo type, using exhaust gas to drive it, but with rather indifferent results. I think this was partly due to the design of the turbine. It is a question, however, whether the exhaust-gas turbine is practicable, except at the high altitudes and where it is desirable not to muffle the exhaust. It is always difficult to find a way to drive the supercharger, especially on engines that have already been built; and it is difficult to eliminate the noise, especially at high speeds.

On two-cycle engines it is necessary to use some sort of piston-type supercharger or else a blower, and especially on Diesel engines, because the supercharger is used all the time. In some development work being done by the American Machine & Foundry Co. on a two-cycle engine, some excellent results have been obtained with a piston-type supercharger. On a little engine of less than 150-cu. in. capacity about 45 hp. is secured at 1500 r.p.m., which is very good.

One trouble in all supercharging work, when an effort is made to cool the gas from the supercharger, is in starting the engine; that is, when the supercharger is used all the time and is direct connected. If the gas is cooled sufficiently for smooth running, it is difficult at the start to avoid a certain amount of backfiring.

T. J. Little, Jr.[6]:—The use of superchargers is bound to come. When we see a result like that which Mr.

[5] M.S.A.E.—Consulting engineer, Indianapolis.
[6] M.S.A.E.—Chief engineer, Marmon Motor Car Co., Indianapolis.

Schwitzer has clearly shown, we realize that a supercharger must be used. Superchargers are not yet sufficiently developed mechanically, but that will come eventually, because thousands of engineers are thinking along this line. Supercharger application must be accomplished. When racing-car engines were reduced to their present size, superchargers had to be used; the cars now look like passenger-cars. We have reached the point in the manufacture of automobiles where the public is requiring superior performance and we are putting ponderous engines, of from 100 to 125 hp., into cars weighing 3500 lb. They are out of proportion, out of reason. The engines are too large and too heavy. Superchargers must be used or the engines will become still larger. The public will demand still more power, because power is being used competitively among the different companies to sell the cars; hence, we must use superchargers and, in my opinion, they will be greatly developed.

Danger in Increased Acceleration

Prof. H. M. Jacklin[7]:—Engines running at low speed with wide-open throttle have at present a drop in pressure through the carbureter and past the throttle-valve of from 0.5 to 2.0 in. of mercury. As the speed is increased the pressure drop increases. I am wondering whether, instead of applying the name "supercharger," we should not apply the word "pressure-restorer." If we build an engine for a given fuel and use the maximum compression-ratio that will not give detonation at the driving speed, we cannot supercharge the engine any more; we cannot force any more air into it without increasing the pressure and without detonation. If we increase the speed of the engine, and the manifold or inlet pressure decreases, we can then use a supercharger. By applying a supercharger we can restore the pressure throughout the whole speed-range; consequently, we can get the power that we ought to get from the engine.

We build the engines with relatively small manifolds to get low-speed operation, as we must maintain rather high manifold velocities to keep the fuel in suspension. As soon as we increase the speed, the pressure drop through the manifold becomes excessive. The supercharger can then come in to restore the pressure and give us low-speed operation, we might say, at high speeds.

I wonder what the psychological effect will be on some operators whose coordination is poor, if the acceleration in the low-speed range is doubled. Such drivers cannot operate with entire safety the cars having the acceleration that is already available; we see them every day climbing up the back of some other car or up a telephone pole. What will happen with such a driver when the acceleration is doubled in that speed range?

Louis Schwitzer[8]:—Professor Jacklin is right. All we really intend to give is 100-per cent volumetric-efficiency. The usual engine runs at about 85 per cent of efficiency up to 1200 r.p.m. At 3000 r.p.m., the volumetric efficiency drops to about 70 per cent. The percentage of increase in power output is 1.8 times the increase in percentage of volumetric efficiency. If the volumetric efficiency of an engine at 3000 r.p.m. is increased from 70 per cent to 100 per cent, the increase in power output will be 56 per cent. This is worthwhile. We do not want to double the acceleration or to double the power; all we want is to replace large engines with much smaller ones that will give the same performance. This can be done only with the aid of superchargers. We do not want to put superchargers on the large engines; but even this can be done economically if anyone wants to get 90 m.p.h. or more. Average cars that will show this performance have engine speeds of 3700, 4200 and even 4400 r.p.m. If the same engine were equipped with a supercharger, it would give the same performance at 3000 r.p.m. This is well worth working for. For lower-speed performance, it is only a matter of the ratio of the supercharger speed or supercharger size to the piston displacement; the necessary flexibility can be secured at any speed desired.

Mr. Little:—Why is it necessary to maintain the present combustion-space in an engine that is equipped with a supercharger; why not increase this space, build up the pressure with the supercharger and increase the power?

Mr. Schwitzer:—It is not necessary to maintain the same combustion-space. In connection with superchargers, all the engines I have known and worked with have been designed specially for supercharger equipment. I agree with Mr. Berger, that a supercharger cannot be attached to an ordinary passenger-car engine and give the performance that it will give if the engine is designed specially for it. Compression-chambers that can be used in connection with superchargers without detonation with available fuels can be designed with a 5.1-to-1 or even a 5.4-to-1 ratio. I ran an engine with a supercharger that had been giving a ratio equivalent to 7.3 to 1 with ordinary Red Crown gasoline without detonation. It seems to me that, with a supercharger, better scavenging and a mechanical turbulence are produced, and these eliminate detonation.

Weight and Cost Considerations

Lon R. Smith[9]:—It seems to me that drivers in general are interested in what the saving in car weight would be, that is, in the frame and engine, and in other savings; and in how these would balance up with the additional cost of applying a supercharger to the present-day car. We all know that we are trying to get more power for our money and more performance and power out of the car. If Mr. Schwitzer has any data on what the saving would amount to, they would be interesting to me as an ordinary consumer.

Mr. Schwitzer:—The price of an article is relative; it depends upon the type of equipment one has, and on how well one knows how to make the article. Although equipped with engines having the same piston displacement, you will find that one car will sell for about $900 while another will sell for about $2,000. If the power-plant with supercharger from the $900 car were put into the $2,000 car and the chassis were made 6, 8 or 10 in. shorter, the weight were 600 lb. less, and the same quality of trimmings were put into the body as in the larger car, this car, with the same riding-qualities, the same seating-comfort, and the same performance, would cost not more than $200 more than the $900 car; and it would be almost $1,000 cheaper than the $2,000 car.

[7] M.S.A.E.—Associate professor of automotive engineering, Purdue University, West Lafayette, Ind.

[8] M.S.A.E.—President and chief engineer, Schwitzer-Cummins Co., Indianapolis.

[9] M.S.A.E.—Vice-president and director of sales, Armacost Automobile Co., Indianapolis.

Generators and Motors for Gas-Electric Motorcoach Drive

By C. A. Atwell[1]

Pennsylvania, Detroit and Chicago Sections Paper *Illustrated with* Photographs and Charts

ELECTRIC transmission is being applied to motorcoaches because of certain advantages which it has over mechanical transmission, such as increased acceleration, easier driving, smoother operation, and greater freedom in the arrangement of the units.

The paper relates principally to the performance characteristics and design features of some of the motors and generators used for this purpose. The speed-torque and electrical characteristics of the generators and motors are described, both separately and as related to the engine performance and the speed and tractive effort requirements of the vehicle. The efficiency is compared with that of the mechanical transmission, and methods of electric braking are described.

Important mechanical requirements for the motors and generators are discussed, and methods of mounting for both the single and double-motor types of drive are illustrated. Advantages of the electric transmission as compared with the mechanical transmission are listed, and it is pointed out that the gas-electric type of drive may play an important part in the present tendency toward a vehicle arrangement in which the engine is placed elsewhere than at the front.

This paper was presented at meetings of the Pennsylvania, Detroit and Chicago Sections, and the oral and written discussion at all three meetings is appended. It includes the views of the representatives of other manufacturers of electrical equipment, of engine builders, and of builders and operators of motorcoaches. Similar transmissions for taxicabs and private passenger-cars are discussed, and data are given on the relative cost, durability, availability and general desirability of electric and mechanical transmissions, with reasons for the views expressed.

Opinion seems to be general that the electric transmission is economically desirable for city use, where stops are frequent, while those who expressed themselves regarding interurban routes considered the additional cost and weight unwarranted for service on them.

USE of a generator and a motor, or some modification of this combination, as a means of transmitting power from a gasoline engine to the wheels of an automotive vehicle is not new. A number of gas-electric rail-cars that were placed in service more than 20 years ago are operating today. The use of this kind of transmission on automobiles is almost as old as the use of mechanical transmission. Reviewing only a few of the many patents covering electric transmissions will show that inventors have been thinking along these lines for many years.

Many of the patented schemes have never developed into practical working equipments. The reasons for this are no doubt varied, but in most cases the desired operating characteristics were not actually obtained, or were obtained by a system inherently complicated to construct or to operate. Development of the modern motorcoach has stimulated new interest in the electric-transmission principle which has placed in service more than 1500 gas-electric coaches during the last few years.

The use of a direct-current generator to convert the engine power, with an entirely separate motor or motors to reconvert the electrical power from the generator, has proved to be the most practical scheme, and nearly all of the gas-electric coaches in operation today are equipped in this manner.

The object of any transmission on a vehicle driven by a gasoline engine is to use the engine power to the best advantage at all times, with as little effort as possible on the part of the driver, and with the minimum wear and tear on all parts of the vehicle. It is natural for those who are familiar with the operation of electrical machinery to expect that this object can be more fully accomplished by an electric transmission than by the clutch and sliding-gear transmission ordinarily used on automobiles. The need for an improvement over the usual transmission is not so apparent on ordinary automobiles, where the number of gearshifts per day and the power required for acceleration are relatively low.

Why the Motorcoach Is Different

However, the problem on the motorcoach, especially in city operation, is much different. The size of the modern coach necessitates the transmission of a large amount of power. Smooth and rapid acceleration are of greatly increased importance in obtaining patronage. Simplified duties for the driver and reduction of concentrated stresses throughout the whole vehicle are items of vital importance to successful operation. The electric transmission produces smooth acceleration because there are no sudden changes in the ratio of engine and propeller-shaft torques. In the absence of these sudden changes, the peak stresses at the time of change are eliminated and the large amount of power being transmitted is handled by well-distributed stresses. Acceleration is rapid, because no time is lost, as when shifting gears with the mechanical transmission. The driver's duties are simplified, because the speed-torque characteristics are such that acceleration is practically automatic, the driver being required only

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to operate the engine throttle and the steering-wheel during the accelerating period.

It is the object to describe in this paper the performance characteristics and design features of some of the motors and generators that are being used successfully on gas-electric motorcoaches today, and to point out the relation of these characteristics and features to the vehicle as a whole.

In general, the problem is to so change the speed-torque characteristics, as furnished by the gasoline engine, as to suit them to the instantaneous requirements of the vehicle for tractive effort and speed. These are principally successions of high tractive-effort at low speed, with gradually increasing speed and decreasing tractive-effort during the accelerating

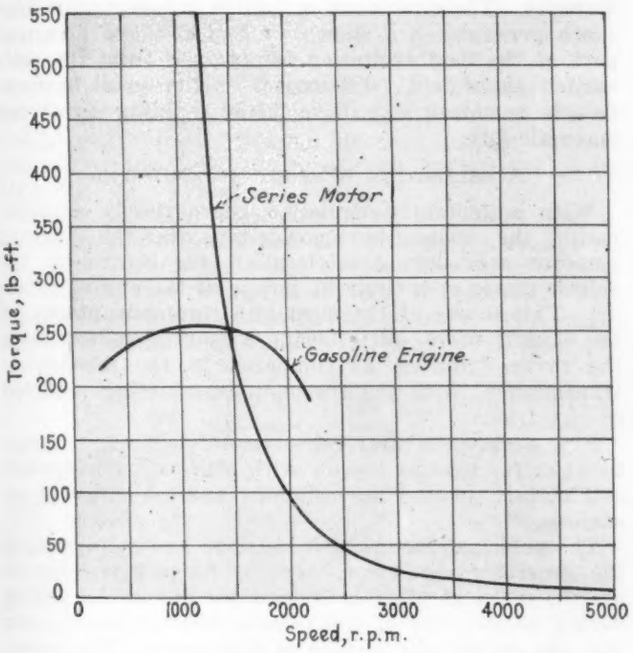

FIG. 1—ENGINE AND MOTOR TORQUES COMPARED

In This Figure the Torques of a Gasoline Engine and a Series-Wound Motor Are Compared at Varying Speeds, Assuming Constant Voltage on the Motor

period, followed by a period of more or less constant speed and tractive-effort. This condition demands a wide variation of propeller-shaft torque over the speed range, while the gasoline engine furnishes a relatively small variation of torque.

SERIES-WOUND-MOTOR CHARACTERISTICS IDEAL

The speed-torque characteristic of the direct-current series-motor is ideally suited to the requirement of the motorcoach, as it has a wide variation of torque with speed. Torque curves of such a motor and of a gasoline engine are shown in Fig. 1, for comparison. The motor chosen is, therefore, logically of the series type. Fig. 2 shows, as an example, the complete performance-curves of a motor used on a two-motor gas-electric motorcoach drive, the speed, torque, and efficiency being plotted against amperes for different voltages applied to the motor.

Having chosen the type of motor to drive the coach, it remains to provide a generator which will properly connect the widely different speed-torque characteris-

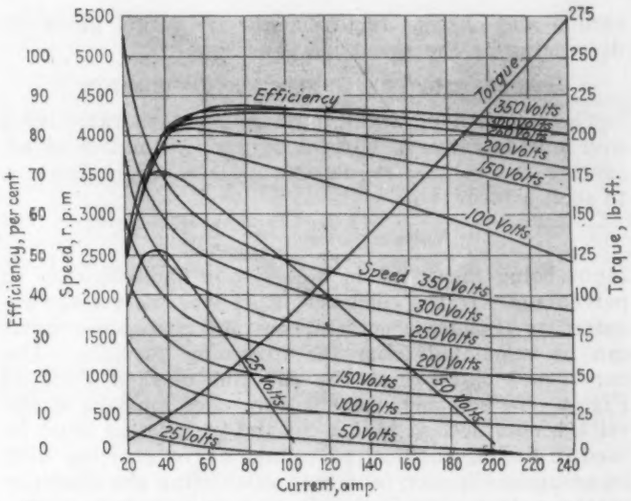

FIG. 2—TYPICAL PERFORMANCE-CURVES OF SERIES MOTOR

These Are the Curves of One of Two Motors Used in a Gas-Electric Motorcoach

tics of the engine and the motor. The operation should be made as nearly automatic as possible.

For simplicity of explanation, a condition of constant engine-speed will be considered, representing constant engine-horsepower with full throttle, as shown in Fig. 3. The generator performance can be analyzed best from a viewpoint of constant available engine-horsepower output or generator-horsepower input, at a certain constant speed. For example, when accelerating, it is desirable to obtain full power from the engine, and the engine should be run at a speed corresponding to what we might call its normal maximum horsepower throughout the accelerating period. Under this condition of constant generator-input a wide variation of current is required from the generator by the motors, due to the changing tractive-effort and speed-requirements of the vehicle. At the instant of start, the motor

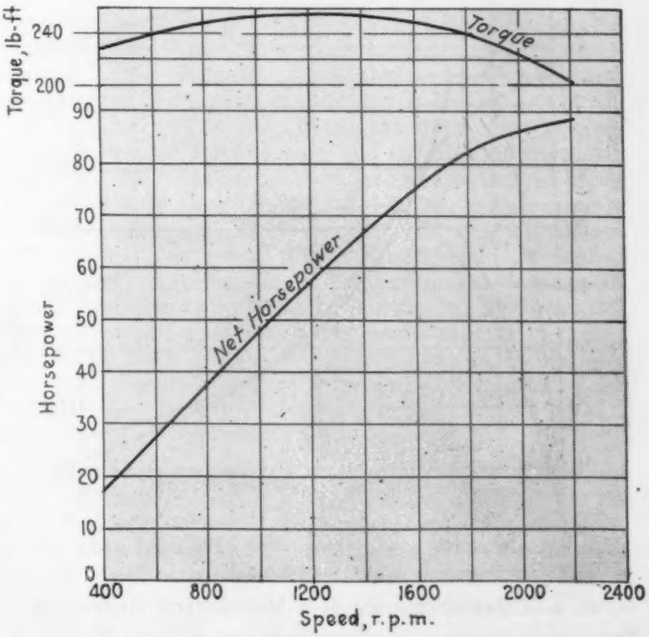

FIG. 3—TORQUE AND POWER CURVES OF A GASOLINE ENGINE

torque and current requirements are large, gradually decreasing as the speed increases.

Adjusting the Generator Regulation

The problem of obtaining constant generator-input over a wide range of current output is a matter of adjusting the voltage regulation, at least approximately, to such a form that

$$\text{Volts} = \frac{7.46 \times \text{input} \times \text{efficiency}}{\text{amperes}}$$

input being measured in horsepower and efficiency in percentage. If the efficiency is known, the voltage required to produce a certain constant horsepower-input can be calculated from the foregoing formula. The curve thus obtained is the full line marked *Volts* in Fig. 4. To be exact, the efficiency used must be at the voltage obtained, so that a cut-and-try process must be used in finding the desired voltage curve, starting with an assumed efficiency and then calculating the efficiency at the voltage obtained. It will be noted from the chart that it is not feasible to obtain constant input at very small ampere values, since the voltage would be very high. The maximum voltage must be limited to a value that is safe in consideration of the flashing characteristics and insulation of the generator and motor. This is shown by the horizontal part of the voltage curve in Fig. 4.

A close approximation of this desired voltage-regulation curve can be obtained in several different ways, all of them based on the principle of suitably increasing the field strength as the current decreases from its maximum value. The shape of the curve is suggestive of differential compounding; but, due to the relatively high current-values at the beginning of acceleration, the armature reaction supplies all the differential action required, and it is sometimes necessary to apply a few cumulative series-turns to the main field to keep the voltage from falling too low at the higher values of amperes. The circuits of a typical gas-electric motorcoach generator are shown in Fig. 5. The principal part of the field excitation is obtained from the self-excited shunt-field. The object of the small battery-field is to obtain a positive initial building up of the magnetic flux.

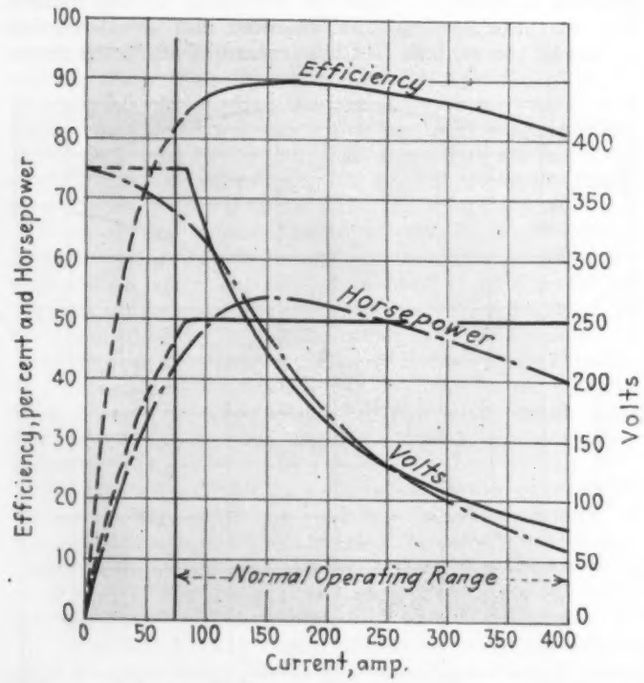

Fig. 4—Characteristics of a Motorcoach Generator

Performance Curves of a Generator Having a Constant Input of 50 Hp. at Constant Speed

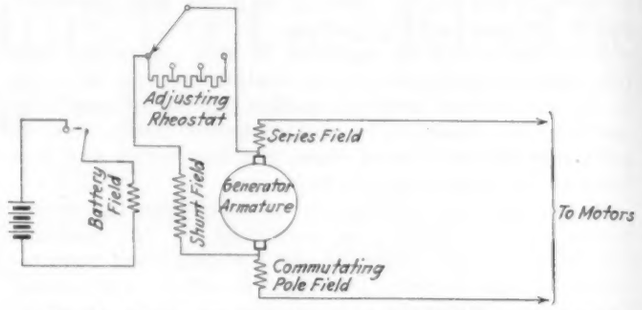

Fig. 5—Field Circuits of a Motorcoach Generator

Accelerating without Gearshifting

With a generator-regulation curve closely approximating the constant-horsepower type over the range of amperes used during acceleration, the control of the vehicle power is entirely by means of the engine throttle. This is one of the most important advantages of the electric drive, as it means a marked reduction of the driver's duties, as compared to the mechanical transmission, with the frequent gearshifting required in city traffic.

Fig. 6 shows typical generator-performance characteristics for various speeds, with efficiency, horsepower and voltage plotted as ordinates against amperes as abcissæ.

The principal factors that must be known in setting the generator regulation correctly for a given engine are the speed at which it is desirable to run the engine during acceleration of the vehicle, and the horsepower that the engine will furnish at that speed. The horsepower to be considered is the net horsepower at the engine crankshaft, under the average condition as operated on the vehicle. Experience has shown that this is about 85 per cent of that shown by the engine manufacturer's factory-test horsepower-curve, which is made with more nearly ideal conditions of cooling, carbureter setting, fuel, and lubrication; and usually without all of the auxiliaries, the air compressor in particular.

If the engine does not supply the power for which the generator is set, the generator will overload the engine and cause it to slow down to a speed at which the engine power is equal to that required by the generator. That such a balancing point will soon be reached is due to the fact that the horsepower of the generator decreases faster with speed than does that of the engine. This can be checked from Fig. 6 by noting, for example, that at 300 amp. the generator horsepower at 1400 r.p.m. is less than 14/16 of that at 1600 r.p.m. If the generator voltage, and consequently its horsepower input, is set too low, the engine will speed up until the generator input does balance the engine output. This feature of the generator characteristics is necessary in order to hold a fairly constant engine-speed with slight variations in engine condition, or because of variations between individual engines.

Knowing the net engine-horsepower at various speeds, the engine-generator balancing-speed can be obtained from the other curves of Fig. 6 by plotting the net engine-horsepower output at the different speeds on the generator-horsepower curves of corresponding speeds. (Curve *A-B*.) This gives a relation between generator amperes and speed for the combined action of generator and engine.

Adjustment Provided for Extra Power

Under certain conditions, such as hill climbing or when increased acceleration-rate is required with heavy loads, it is desirable to operate the engine above its "normal maximum" speed and power. Assume, for example, that the usual speed during acceleration is between 1400 and 1600 r.p.m. A speed of 1800 to 2000 r.p.m. would supply the extra power needed in an emergency. This requires a change in generator setting that will allow the engine to reach this speed. Such a change is accomplished by inserting a resistance in the shunt-field circuit. This lowers the generator voltage and horsepower for a certain speed at a given current, and allows the balancing speed and horsepower to be higher.

This seems like a paradox at first thought, but it should be remembered that this is simply a change in the generator characteristic which allows it to balance the engine at a higher speed and horsepower. The change in generator characteristic resulting from weakening the shunt field is shown in Fig. 7. The insertion

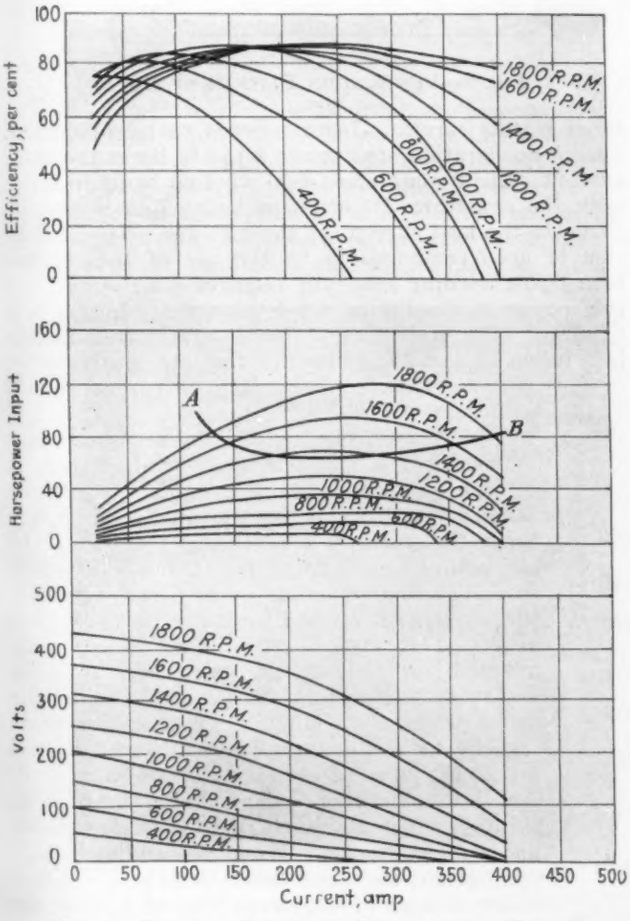

Fig. 6—Typical Generator-Performance Curves

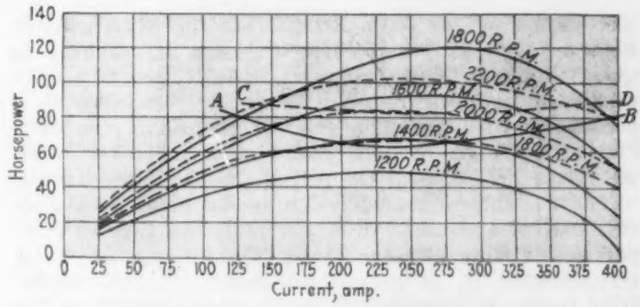

Fig. 7—Effect of Introducing Resistance into the Generator Shunt-Field

The Full Lines Represent the Generator Input with Normal Setting and the Dotted Lines Show the Effect of the Resistance. Curves *A-B* and *C-D* Represent Corresponding Engine-Generator Balancing-Conditions

of resistance in the field circuit for this purpose cannot easily be made automatic, as it is only under special conditions of extra tractive-effort requirements that it is desirable to work the engine at the speed equivalent to maximum horsepower. A normal setting to operate at this speed would be detrimental to the engine life.

One method which has proved quite satisfactory is to provide a foot switch which normally short-circuits the resistance and which opens and places the resistance in the circuit when depressed. Another method is to provide a field rheostat having several notches, as shown in Fig. 5, with a handle on the instrument board. The amount of speeding up of the engine can then be varied in steps according to the service conditions encountered. An advantage of this arrangement is that this rheostat can be used as an adjustment for engine condition. If for any reason the engine horsepower becomes low the generator setting can be changed so that the desirable power will be maintained. It should be remembered that the operation of the foot switch or rheostat is only an occasional duty for the driver, not a regular duty.

An important feature of the generator design affecting acceleration is its ability to build up quickly when the driver steps on the accelerator pedal and the engine speed changes from idling to its normal speed for acceleration. This characteristic is obtained by proportioning the field coils for minimum self inductance.

It may be well to note here that the engine characteristics desired for use with the gas-electric drive are somewhat different from those for the mechanical drive. A high rate of speed pick-up and higher horsepower at the high speeds probably are the two most important differences. The use of a heavy flywheel is not desirable, and the maintenance of high torque at low speeds is not so necessary as with the mechanical transmission. Several engine-manufacturing companies have made studies of these requirements and have made changes that have resulted in much improved acceleration of the vehicle.

Electrical Efficiency

One of the questions most often asked about the gas-electric type of drive is: "What is the efficiency of the electrical apparatus?" Generators and motors necessarily have losses, and it is only fair that the inquirer should know accurately what these losses are. Fig. 8 shows the combined efficiency of the motor of Fig. 2 and the generator of Fig. 6. The efficiencies correspond to the engine-generator balancing-speeds, which are

also indicated. It is important that the efficiencies be held as high as possible for the size of machine in question at the heavy ampere loads. This is accomplished by using a design with as low resistance as is consistent with the allowable weight. The use of a "copper" design in both motor and generator minimizes the I^2R losses at the initial accelerating currents.

The mechanical transmission is reported to have an efficiency of around 88 to 95 per cent, and a direct comparison of this efficiency with that of the electrical transmission is, of course, unfavorable to the latter. It is incorrect, however, to draw conclusions from the comparison of these efficiencies alone, since the real comparison is that of fuel consumption and comparative acceleration. Road tests of similar vehicles, some equipped with mechanical and others with electric transmissions, have indicated with a fair degree of accuracy that fuel consumption with the electric drive is 10 to 20 per cent greater than with the mechanical drive. The improved acceleration of the electric transmission, with resulting speeding up of schedules, is now well established. Knowing that the fuel item usually is less than 15 per cent of the total expense of motorcoach operation, and considering the better use of the engine power during acceleration, the operator does not need to be concerned by a direct comparison of the efficiencies of the electric and mechanical transmissions.

It is often valuable to have in a single set of curves the combined balanced performance of engine, generator and motors. Fig. 8 represents such a combined curve, and gives the values of the different items plotted against the common base of generator amperes. Such a combined curve can be obtained from the engine, generator, and motor-performance characteristics, or, if all are not available, it can be obtained by an actual test of the apparatus on the vehicle by taking readings over the range of speeds and tractive efforts.

Use of Commutating Poles

Good commutation and freedom from flashing are essential to long life and low maintenance cost of any direct-current machine. The commutator, brushes and brush holders are wearing parts, and they must be considered with the idea of making the wear and resulting maintenance as low as possible. Continual sparking at the brushes not only produces wear of these parts but often is accompanied by flashing or arcing across the face of the commutator from one brush to another, or to some grounded part of the machine. The worst conditions for sparking are those of high ampere-load and high speed, and commutating poles are necessary on the generators and motors for gas-electric coaches because of the high instantaneous starting-loads on both motor and generator, and because of the relatively high speed of the motor.

The non-commutating-pole machine cannot be designed for sparkless commutation at all loads, because of the shifting of the magnetic field by the armature reaction. The commutating pole compensates for this field-shifting and produces practically sparkless commutation, with comparative freedom from flashing over the wide range of speed, voltage and current encountered in this service. Instantaneous values of current during acceleration often reach 3 to 3½ times the rated current. The commutating-field winding being in series with the armature, its compensating effect is proportional to the load current of the machine. The production of good commutation by the use of the commutating-pole winding naturally requires some power, and this power is the I^2R copper loss in the interpole-field winding. The resistance of the interpole field usually is between 15 and 25 per cent of the total generator or motor resistance, depending on several details of design.

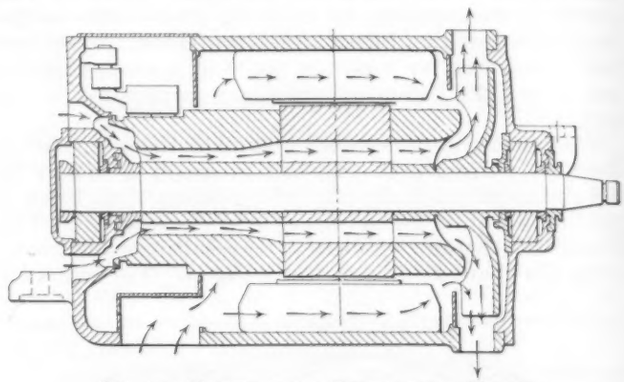

Fig. 9—Ventilation Diagram of Motor

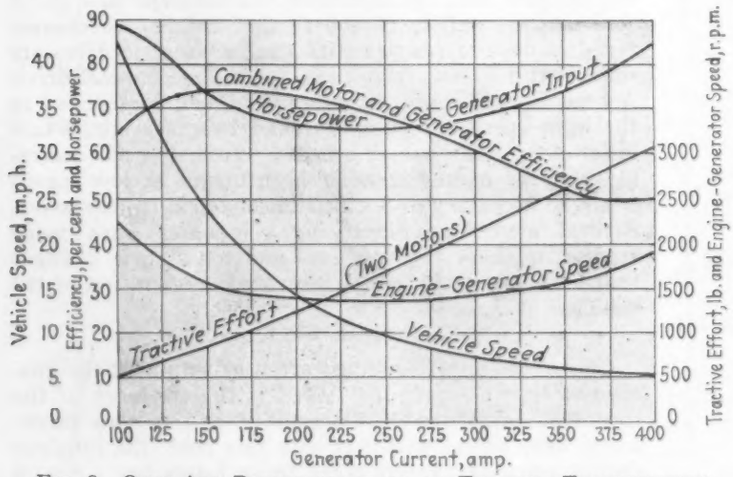
Vehicle Speed, m.p.h.
Efficiency, per cent and Horsepower
Tractive Effort, lb. and Engine-Generator Speed, r.p.m.
Generator Current, amp.
Combined Motor and Generator Input
Horsepower
Generator Efficiency
(Two Motors)
Engine-Generator Speed
Tractive Effort
Vehicle Speed
0 5 10 15 20 25 30 35 40
0 10 20 30 40 50 60 70 80 90
0 500 1000 1500 2000 2500 3000
100 125 150 175 200 225 250 275 300 325 350 375 400

Fig. 8—Over-All Performance of an Electric Transmission

This Chart Is a Combination of the Performance of the Engine in Fig. 3, the Generator in Fig. 6, and the Motor in Fig. 2. The Gear Reduction Between Motor and Axle Is 11 to 1; Tires Are 36.8-In. Diameter

Two types of electric braking are in use now on gas-electric motorcoaches. One of these is straight dynamic braking, which is accomplished by disconnecting the motor or motors from the generator, reversing the fields, and connecting to a loading resistance. The effect is that the motor builds up as a series generator, exerting a reverse torque on the propeller-shaft. This method of braking is especially adapted for use as an emergency brake in traffic, or for holding the vehicle at a definite speed when descending a grade. The braking effect has a definite relation to motor speed and to the value of the resistance in the circuit. An electric-braking pedal usually is provided, through which the value of the braking resistance can be varied. When descending a uniform grade, the coach can be kept at a constant speed with no effort except that of holding the pedal in a certain position.

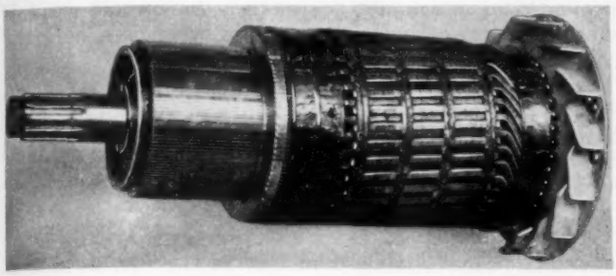

FIG. 10—ARMATURE OF MOTORCOACH GENERATOR

The other braking method in use is to reverse the connections of the motor to the generator and insert a resistance in the circuit. With this connection, depression of the accelerator pedal tends to run the motor in the reverse direction. This type of braking usually is reserved for use as an emergency brake, as its severity is dependent upon the driver's judgment in opening the engine throttle.

GENERAL MECHANICAL REQUIREMENTS

The general mechanical problem of the design of the generators and motors is to provide machines of sufficient capacity to produce the desired performance as to acceleration and running speed, with due consideration also to the following conditions:

(1) Minimum weight
(2) Minimum maintenance
(3) Shape adapted to mounting in the vehicle, with regard for accessibility, ground clearance, and minimum floor interference
(4) Quiet operation

Light weight is an essential in all motorcoach equipment, and it is obtained in the motor and generator by the use of high-strength aluminum castings where steel or iron is not needed as a part of the magnetic circuit. The use of asbestos and mica insulation, permitting higher operating temperatures of the windings; a highly efficient unidirectional ventilating fan on the armature shaft; and relatively high peripherial operating speeds are additional factors for obtaining a high horsepower-rating per unit weight of machine.

A special scheme of ventilation is used, which prevents the ventilating air from coming into contact with the commutator and brushes. This keeps dust and spray from these current-carrying parts, and is an important factor in obtaining long brush-holder, carbon-brush, and commutator life. Fig. 9 indicates the method of baffling the ingoing air to keep it away from the commutator and brushes.

The armature bearings are of the ball or roller type. Long life is obtained by selecting bearings that are suitable for the loads and speeds encountered, and by the use of bearing enclosures that keep in the lubricant and keep out the dust.

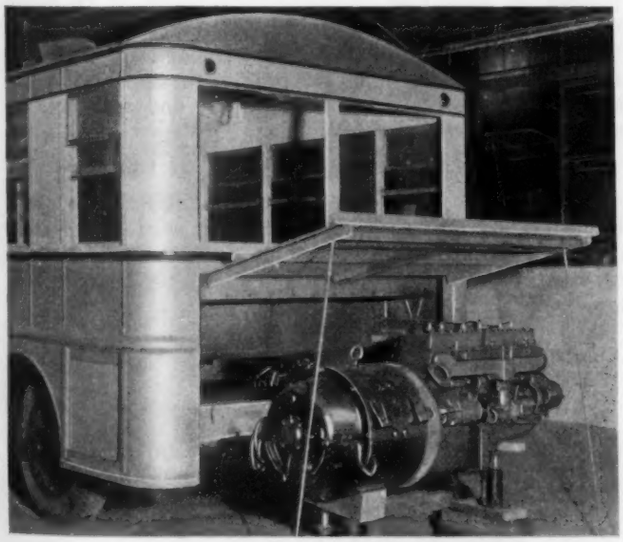

FIG. 11—ENGINE-GENERATOR UNIT
This Self-Contained Powerplant Is Mounted at the Rear of the Vehicle

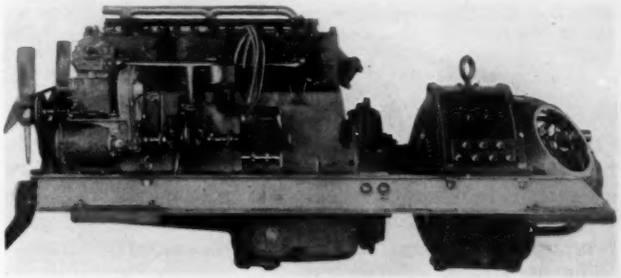

FIG. 12—FRAME MOUNTING OF ENGINE AND GENERATOR
This Powerplant Is Mounted in the Conventional Position in Front and Can Be Removed Conveniently

Quietness of operation of both motor and generator is necessary, to be in keeping with the other features of smooth operation of the gas-electric coach. Special attention must be given to this point on account of the relatively high speed of the motor armature and the rapidly changing speed of the generator armature each time the accelerator pedal is depressed. Brush noise is minimized by special brush-holders with inclined carbons; fan noise, by the correct shaping of fan and air outlets; and magnetic noise, by the use of skewed armature-slots and proper proportioning of all parts of the magnetic circuit subject to flux variations.

The armatures are made safe for the high peripheral speeds encountered by special banding and commutator construction and by accurate dynamic balance. Fig. 10 illustrates the construction of a typical armature.

TYPES OF GENERATOR MOUNTING

The general shape of the generator depends on its method of connection to the engine and its position in the vehicle. The most satisfactory mechanical connection requires accurate alignment between the generator and engine. In Fig. 11 is seen a generator that is bolted solidly to the engine through an adapter casting, accurate alignment of the generator-shaft, with the engine crankshaft being assured by means of bored and turned fits. The generator has but one bearing, the engine end of the armature shaft being piloted in a bushing in the end of the crankshaft, with a flexible-disc coupling for power connection. This unit powerplant can be removed very easily, especially when located in the unique position shown in Fig. 11, across the rear end of the vehicle.

Fig. 12 shows a generator and engine mounted on a

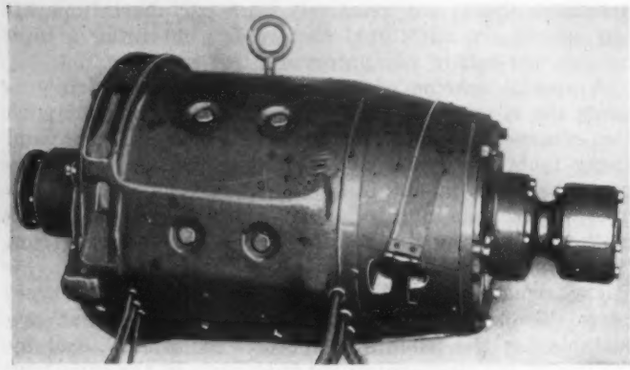

FIG. 13—GENERATOR DRIVEN THROUGH HOLLOW ARMATURE-SHAFT

To Allow for Mounting Close to the Engine, with Universal-Jointed Shaft Drive, the Armature Shaft Is Made Hollow. The Drive-Shaft, Which Is Seen Projecting at the Left, Drives through the Universal-Joint at the Extreme Right of the Cut

structural-steel sub-frame and connected by means of a flexible-disc coupling. This powerplant is located in the conventional position, but it can be removed more easily than the usual engine. The side members of the sub-frame act as slide rails resting against the corresponding supporting members of the chassis frame.

The generator shown in Fig. 13 is particularly adapted for mounting directly back of the usual engine position without necessarily being in accurate alignment. An adapter, bolted to the engine, supports one end of the generator at two points, one of which is shown drilled at the left, while the other end is clamped against a cross member of the chassis at the cylindrical surface next to the rear head of the unit. The generator can be lowered from its position by taking out the two front supporting-bolts and unbolting the semicircular clamp at the rear. The engine power is transmitted to the generator through two flexible couplings, one at each end of a small-diameter shaft which passes through the center of the hollow armature-shaft. This arrangement is practically equivalent to connecting the engine to the generator by a propeller-shaft and two universal-joints, yet allows the generator to be very close to the engine so that there will be little interference with the floor just back of the dash. The outline of the generator is suited to this location. The relatively small diameter results in the minimum of floor interference and the necessary ground clearance.

LATITUDE IN MOUNTING OF MOTOR

The fact that the motor is mechanically independent of the engine allows considerable freedom in its location. The factors determining its position are the method of gearing to the axle and the shape of the chassis or bogie truck.

Fig. 14 illustrates a type of motor suited to being supported from two cross-members of the chassis. The shaft-extension end faces the rear axle and is bolted up to one frame-cross-member through the two support-lugs, one of which is seen at the right in the illustration. The other end is supported from a second cross-member by a single bolt through the lug shown at the left. Two motors of this type are placed side by side, each driving one rear wheel through a propeller-shaft, two universal-joints and a worm-gear reduction. This drive eliminates the differential and allows greater ground-clearance under the motors than would exist if a single motor of twice the capacity were used with the same height of floor.

A single motor can be used if the floor is raised slightly; and it has several points of advantage over the double motor, since it permits the use of a conventional rear-axle, reduces the weight and the number of pieces of apparatus, and has better electrical efficiency than two smaller motors.

Another method of using an ordinary rear-axle is to mount two small-diameter motors in tandem, as shown in Fig. 15. This requires shaft extensions on both ends of one of the motors and a coupling between the two. The mounting feet are placed at the sides, in this case.

Fig. 16 illustrates a type of drive developed by one builder for his eight-wheel gas-electric motorcoach. Each vehicle has two bogie trucks, the outstanding advantage of their use being the short turning-radius

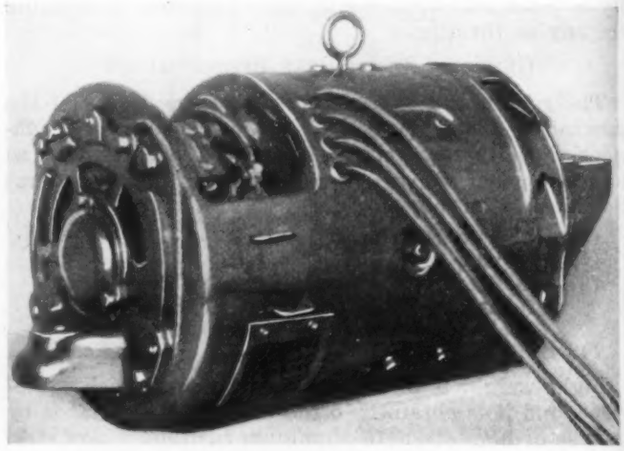

FIG. 14—MOTOR WITH SUPPORTING LUGS AT THE ENDS

that is possible with a coach of considerable length. The motors are provided with trunnions and are suspended on links that are free to oscillate on trunnion brackets fastened to longitudinal channels of the bogie frame. A spherical casing, the two sides of which are fastened rigidly to the housings of the motor and of the axle, encloses a single universal-joint and also acts as a motor support.

ADVANTAGES AND DISADVANTAGES LISTED

In conclusion, it may be well to enumerate the more important advantages and disadvantages of the electric drive for motorcoaches, as compared with the mechanical transmission. The advantages may be listed as follows:

(1) Increased schedule-speed can be sustained, resulting in more revenue-miles per day
(2) Driver's duties are decreased, resulting in a reduction in the number of accidents and a more attractive job for the driver
(3) Smoother operation, resulting in increased patronage and longer life of the engine, chassis, and the vehicle as a whole
(4) Greater freedom of body arrangement, the engine being mechanically free from the propeller-shaft

Against these advantages may be listed the following disadvantages of electric transmission:

(1) Increased first-cost
(2) Increased weight
(3) Slightly increased fuel-consumption

The future of the gas-electric motorcoach and the general adoption of the electric transmission depends, of course, on the economic evaluation of its advantages as compared with its disadvantages. This evaluation can be made accurately only by comparison of operating records for a period of years. Some operators have been convinced of the advantages to the extent of placing in operation large numbers of gas-electrics, while others are not yet convinced. It is significant that the largest users of gas-electric coaches have increased the number of vehicles of this type.

It is not the intention to provide figures in this paper for an economic comparison of the two types of transmission but rather to explain the working principles and design features of the electric drive so that, with a clearer understanding of its performance, operators may draw their own conclusions. Advantage (4) should not be passed over lightly. Recent developments made by builders indicate that the general shape and arrangement of the future motorcoach for mass transportation is to be considerably changed from the present conventional form. The tendency seems to be toward the form of a street-car with pneumatic tires, placing the engine elsewhere than at the front. The electric drive will, no doubt, be an important factor in working out the most suitable arrangement, because of the greater freedom it gives in the location of the engine.

[2] M.S.A.E.—Transportation engineer, Six Wheel Co., Philadelphia.

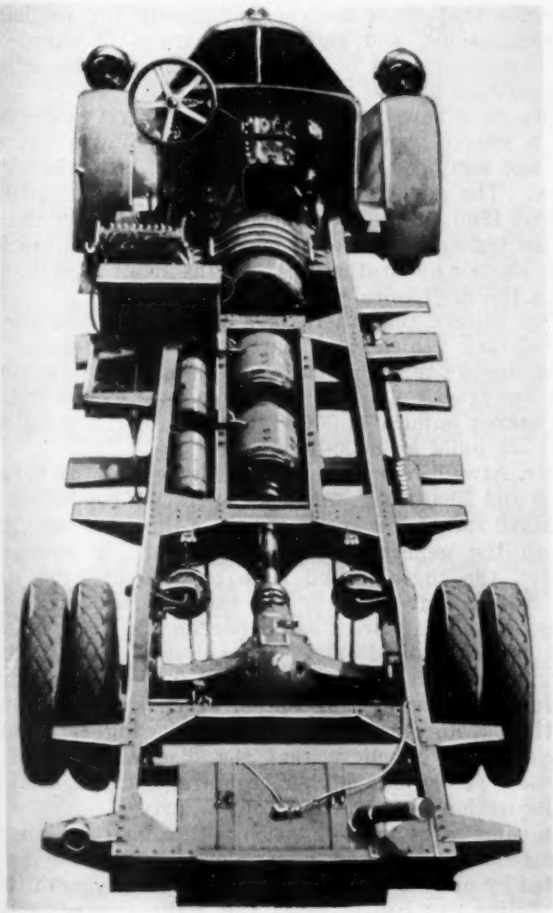

FIG. 15—MOTORCOACH CHASSIS WITH TANDEM MOTORS

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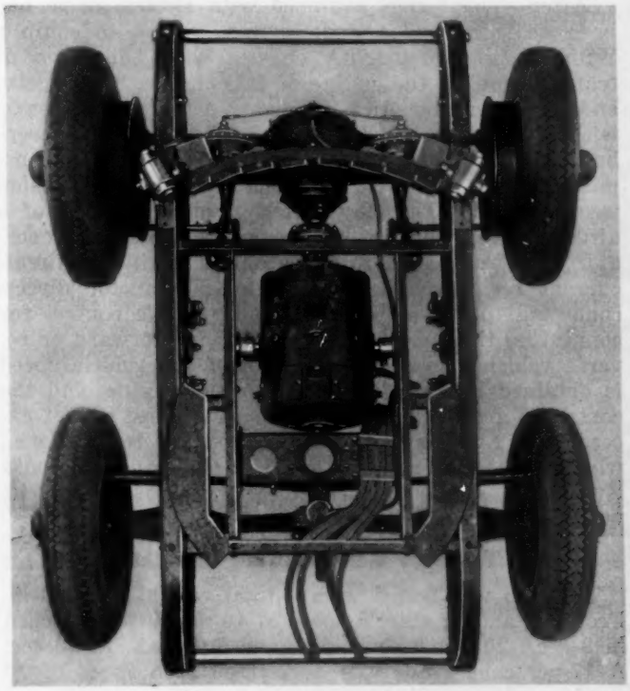

FIG. 16—BOGIE TRUCK OF EIGHT-WHEEL COACH

The Motor Is Supported from the Bogie Frame by Links at the Trunnions and form the Axle by a Spherical Housing around the Universal-Joint

Characteristics of Generators and Motors for Gas-Electric Traction; C. A. Atwell, *Electric Journal*, July, 1926, p. 363.

The Electric Drive as a Motorcoach Transmission; Charles Froesch, THE JOURNAL, September, 1927, p. 268.

THE DISCUSSION AT PHILADELPHIA

E. L. CLARK[2]:—Has Mr. Atwell comparative figures on the acceleration of otherwise similar vehicles with gear and electric transmissions?

C. A. ATWELL:—It is hardly possible to secure accurate figures that will cover the general case. We have made many tests on experimental motorcoaches, but the results are not entirely consistent. In general, the acceleration with the gear transmission is slightly better at the very first; but over a period of 20 sec. or longer, the electric transmission accelerates faster. Under test conditions, the electric transmission is about 5 or 10

per cent better in coming up to the full speed; but, in regular all-day service, the coach with electric transmission will cover 10 to 20 per cent more miles per day. Part of this undoubtedly is due to the fact that the driver gets tired in making about 3000 gearshifts in the course of the day.

GUY W. WILSON[3]:—The successful and economical operation of the gas-electric-drive motorcoach led to the consideration of a taxicab with the same type of transmission. The Yellow Cab Co. of Philadelphia and the General Electric Co. have cooperated in this development to the extent of building and testing several cabs equipped with electric drive. While this development is still of a more or less experimental nature, the equipment has been worked out in detail to a point where successful operation can be assured.

After several cabs equipped with electric drive had been designed and tested, it was decided to equip a Willys-Knight Model-70A chassis with this type of transmission, as the engine of this chassis has the size and the characteristics desired. A special rear-axle with 9.85-to-1 reduction and a special taxicab body were built and installed, the conventional clutch and transmission were removed, and the electric transmission was installed. The electrical equipment consists of a direct-current shunt-wound commutating-pole generator direct-connected to the gasoline engine, a direct-current series-wound commutating-pole motor direct-connected to the drive shaft, and suitable control for connecting the generator and motor for forward or reverse vehicle movement. Control of the vehicle speed is obtained by throttle control of the engine, and the control is arranged so that the engine speed cannot exceed 2000 r.p.m. at any vehicle speed up to 40 m.p.h., which is the free running speed of the loaded cab on a level road. This completed cab, without passenger load, weighs approximately 3900 lb.

TESTS OF GAS-ELECTRIC TAXICAB

This cab was tested with a total weight of 4600 lb. From a standing start a speed of 10 m.p.h. was reached in 3 sec.; 20 m.p.h. in 6 sec., and 30 m.p.h. in 12 sec. A 17-per cent grade was negotiated at a speed of 10 m.p.h., and a gasoline consumption of 15 miles per gal. was obtained on a cross-country run. In regular taxicab service, 13.2 miles per gal. was obtained.

These records show that a vehicle with a low power-weight ratio, equipped with electric transmission, can give very satisfactory and economical performance. The performance probably is explained by the facts that, with electric drive, the engine can be run at its maximum-power speed at all vehicle-speeds, and that no time is lost in gear changes; and the fuel economy is due to the fact that, when the cab is in motion, the engine is always at almost full throttle, under which condition its thermal-efficiency is best.

The flexibility and ease of operation of the electric-drive cab probably is best told by an experience during our tests at Lynn, Mass. To obtain a true comparison, we hired a mechanical-drive cab and a driver for an afternoon. Part of the routine test consisted in climbing and stopping and starting on a 17-per cent grade. After the hired driver had gone through this performance several times with the mechanical-drive vehicle, he was transferred to the gas-electric. After his first trip, he said: "I wish I could have a cab like that to drive all the time."

Since it is almost impossible for a driver to abuse the electric drive, it seems reasonable to expect lower maintenance and depreciation charges for a taxicab having this type of drive, as has been found with the gas-electric motorcoach. The questions of safety, comfort and reliability are of vital importance. The electric transmission promotes safety by relieving the driver of his duty of shifting gears, provides increased comfort by eliminating the shock and noise of gear changes, and makes a more reliable vehicle by reducing the number of wearing parts.

P. M. HELDT[4]:—How much weight is added to the conventional taxicab by equipping it with an electric transmission?

MR. WILSON:—The equipment we used added about 650 lb. That can be reduced by 100 lb. in another design, but at least 450 or 550 lb. will be added.

VIEWS OF A MOTORCOACH BUILDER

A. K. BRUMBAUGH[5]:—The engineering department of the White Co. has been following the development of electric transmissions closely, and has come to the conclusion that its success depends largely on the development of a suitable engine. Most of the 1500 gas-electric motorcoaches that now are running are built on chassis that were designed originally for mechanical transmissions, and significant changes in engine and transmission must be made in developing the ultimate gas-electric vehicle.

We have now brought out a gas-electric model based on a geared-transmission model weighing about 8000 lb. and equipped with a 4⅜ x 5¾-in. six-cylinder engine. The gas-electric chassis weighs about 11,400 lb. About 1200 lb. has been added by the necessary changes in the frame, rear axle, springs and supporting brackets. The electric apparatus itself weighs about 2200 lb. more than the mechanical parts that it replaces.

We believe that there is a definite market for the gas-electric vehicle, and that its use will increase. The advantages cannot be had for nothing; we build motorcoaches practically on a basis of so much per pound, and we cannot build a 11,000-lb. chassis for the same price that we build an 8000-lb. chassis.

Mr. Atwell's curves show the engine running between 1400 and 2000 r.p.m. under all operating conditions. It is never run at low speed, and it is throttled very little. When the generator field is reduced for emergency power, the engine speed rises to 2200 or 2400 r.p.m. We believe that an engine for this service needs a very heavy crankshaft with seven bearings, a very substantial crankcase, and salt-cooled valves. As Mr. Atwell says, it is desirable to have an engine with the horsepower sustained at high speed, which involves changes in timing, higher compression and the highest possible efficiency. We believe that the disadvantages of increased weight and higher cost are met, and that the real question is the fatigue of the driver.

In some cases where a coach with a geared transmission requires two men, a gas-electric coach can be operated by one man. Relieved of the job of gearshifting, the driver can collect fares and make change, and he can probably get the coach under way more quickly.

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[3] Jun. S.A.E.—Engineer, gas-electric bus equipment, General Electric Co., Schenectady, N. Y.

[4] M.S.A.E.—Engineering editor, *Automotive Industries*, Chilton Class Journal Co., Philadelphia.

[5] M.S.A.E.—Assistant commercial engineer, White Motor Co., Cleveland.

Recently we have produced a chassis which approaches our ideal of what a gas-electric motorcoach should be. As a result of our brief experience, it has 30 to 40 per cent more power than would be required for a mechanical drive; and every comparison we have made shows an outstanding superiority over coaches that are made by modifying chassis that were designed for mechanical drive.

A. M. LEONI[6]:—Would it not be an improvement to gear up the generator so that the engine speed can be lower and the generator speed higher?

MR. ATWELL:—That might be worth investigating. It would be desirable in that it would make possible the use of a smaller generator, but the necessary gears would be objectionable. The present automobile is the result of long development; no doubt there will be further development of generators and motors for motorcoaches, as they have had the benefit of only 3 or 4 years' development so far.

MR. BRUMBAUGH:—It is necessary to operate the engine at about the present speeds to obtain the power that is needed. The engine would need to be large to develop the same power at 1200 or 1400 r.p.m. Auxiliary apparatus also takes up room. The requirements now are for air compressors up to 6000 or 9000-cu. ft. capacity and generators of 750 or 800-watts capacity.

A LEADING OPERATOR SPEAKS

H. B. HEWITT[7]:—Gas-electric motorcoaches have been operated approximately 35,000,000 miles under Mitten management in Philadelphia and Buffalo. We believe that the additional first-cost and extra weight are more than compensated for by the faster schedules and reduction in platform costs made possible. Schedule speed probably is faster in Philadelphia than in any other motorcoach operation in the Country, because of the 100-per cent gas-electric equipment.

Experience indicates a life of 10 years or longer for gas-electric motorcoaches; some of the gas-electric omnibuses that are operating in London are about 15 years old. Maintenance cost is substantially less than for vehicles having geared-transmissions, and our experience indicates that longer periods between overhauls are permissible. Only recently we extended the period between scheduled engine repairs from 8000 to 25,000 miles, and some of the coaches are operating in Philadelphia after running more than 150,000 miles without a general overhauling.

P. M. HELDT:—Of the 1500 coaches so far equipped with electric drive, how many are of the double-deck type?

MR. ATWELL:—Most of the double-deck vehicles are in Philadelphia. There are about 200 of them, some seating 67 and others 70 passengers.

MR. HEWETT:—Vehicles that are operated by one man are being increased in capacity to accommodate 71 seated passengers. Some of the single-deck coaches seat 33 passengers and those of the deluxe type seat 27 to 29.

A. H. ABELL[8]:—The Mack Company, which has made a number of gas-electric coaches, is now designing one of a new form having the powerplant in the rear. It looks much like a street-car; the driver sits well ahead of the front wheels and has a clear vision. For a given length, the seating capacity is greater than with the engine arranged as usual. This model is not yet on the market, but it is being tested in operation.

CHAIRMAN E. W. TEMPLIN[9]:—Do you believe that the motorcoach resembling a street-car will supersede that with the engine in front?

MR. ABELL:—There is much interest in vehicles of this form, and I believe there will be a greater development along that line.

DO NOT BE BOUND BY CONVENTION

H. C. GIBSON[10]:—The gas-electric motorcoach is at a disadvantage because of increased weight and poorer economy in fuel, tires and other items. Is it not possible to eliminate these disadvantages by departing from the conventional arrangement that has been developed for the mechanical-drive coaches? For instance, is the chassis frame necessary in a gas-electric vehicle? The elimination of the frame is no new idea, but would it not be more practicable with electric transmissions than with mechanical?

MR. ABELL:—That idea has been embodied in the experimental vehicles I mentioned.

MR. ATWELL:—I should like to ask Mr. Brumbaugh what his experience has indicated to be the maximum speed at which present engines can be operated with economy? The generator can be made for any speed; but we would like to have the speed high, because low speed requires larger units.

MR. BRUMBAUGH:—With a given weight of material, more power can be obtained at higher speed. At some speed there is a proper balance between the amount of material and the results. We believe that engines can be built that will operate between 1400 and 2000 r.p.m. with adequate life; and that seems to be the speed that has been arrived at by the two large electrical-manufacturers working independently. I believe that no ordinary engine will endure at that speed. It should have the dependability of a marine engine with much lighter weight, and it is about the hardest service to which the internal-combustion engine can be put.

MR. LEONI:—If a gas-electric taxicab were designed for a 30-m.p.h. maximum speed, would it not be possible to use a smaller engine and smaller electrical equipment?

MR. HEWITT:—It is necessary to remember the desire of the American man to hurry. He does not like to see other cars pull away from him; besides, a margin should be allowed in the size of the engine to permit running for a long period without overhauling.

MR. LEONI:—Are not six-cylinder engines used in taxicabs because of their greater flexibility, and will not four-cylinder engines be satisfactory with an electric drive?

A VISITOR:—The four-cylinder engine would be satisfactory if it could be balanced to eliminate vibration.

During the last few years I have had some strange experience with engine builders, partly explained by my own ignorance of the fact that their power readings are taken under ideal conditions which are not maintained in service; at least we find about 10 hp. less delivered after the accessories have been added. By rearranging the valve timing to suit conditions, engine makers have been able to give about 20 per cent increase in power at

[6] Consulting mechanical engineer, Philadelphia.

[7] Superintendent of rolling stock and shops, Philadelphia Rural Transit Co., Philadelphia.

[8] Commercial bus engineer, International Motor Co., New York City.

[9] M.S.A.E.—Chief engineer, Six Wheel Co., Philadelphia.

[10] M.S.A.E.—Consulting engineer, Philadelphia.

1800 r.p.m. Other improvements can be made sometimes.

MR. HEWITT:—In the engine to which Mr. Wilson has referred, the fan alone absorbed 11 hp. We found that sufficient cooling can be obtained with the fan running at half its original speed, with a reduction of more than one-half in the power required. In one type of engine the compression ratio was increased from 4.6-1 to 5.56-1, with an increase of 30 per cent in power. In another engine the power was increased in the same proportion by better vaporization, with the same fuel-consumption per brake horsepower.

Superchargers are being considered by some American manufacturers. It is claimed that they will nearly double the power of a motorcoach engine.

THE DISCUSSION AT DETROIT

QUESTION:—What will the instrument board look like on a vehicle of the sort Mr. Atwell has described?

C. A. ATWELL:—There is not much more on the instrument board than in other motorcoaches. In some cases there is a handle for changing the setting of the generator shunt-field. Another difference is that sometimes a special floor-plate is required just back of the dash to clear the generator, which interferes with the usual position of the floor.

F. A. WHITTEN[11]:—The real advantage of a gas-electric transmission is not that it eliminates the clutch and geared transmission, but that it enables the coach to maintain a higher average speed over a route with many stops. It is a transmission which gives an infinite reduction at the start, and changes automatically, gradually and smoothly, until it gives about the same reduction as a mechanical transmission.

In recent tests we have found that it is possible to accelerate a coach weighing over 20,000 lb. from a standstill to 20 m.p.h. in about 12½ sec. We have also found that the right driver with a four-speed geared transmission can get to the same speed in about the same time, but that the passenger would not like it so well. It takes a skillful driver to do that, and it probably is much harder on the mechanism and on the passenger than is the electric drive.

I think that the largest purchasers of electric-drive coaches are also the largest purchasers of mechanical-drive coaches, which indicates that there is a field for each. No one yet knows exactly what is the dividing line between these two fields.

DESIGNERS MUST KNOW NET HORSEPOWER

A. I. BUTLER[12]:—One point that I should like to bring to your attention is that the engine horsepower actually available is very much less than the amount shown by the manufacturer's test curves, which are, of course, made under ideal conditions and do not include all auxiliaries. The designer of the electric transmission has to start in his design with the engine characteristics, and he should have accurate information as to what torque-speed characteristics he can depend upon. It now is necessary to calculate the horsepower required by the auxiliaries, which is unsatisfactory. It would be highly desirable if the engine manufacturer's tests could be made to include all auxiliaries and could be made under conditions that are more nearly like service conditions, so that the electric-transmission designer could have a definite and dependable engine characteristic to start with.

In regard to the generator, Mr. Atwell states that it usually is necessary to provide a few turns of cumulative series-field to obtain the right characteristics. Another design would be to use a shunt field only for main excitation, together with a battery-excited teaser-field for initial build-up. Experience has shown that the characteristics of this arrangement are well suited for a connecting link between the engine and the motors.

Mr. Atwell has described a method of operating the engine above its "normal maximum" speed and horsepower on certain occasions, such as hill-climbing or when a higher acceleration rate is desired, and states that a foot switch or an extra field rheostat, manually operated, is used for making the necessary connection changes. It has been found possible and desirable to make this feature automatic by the use of a simple current-relay inserted into the generator-armature circuit, which is set to operate at approximately 10 per cent above normal-maximum accelerating-current, at which point it opens a set of contacts and throws the correct amount of resistance into the generator field-circuit. Another method would be to combine a switch with the foot throttle, to operate only after full-throttle position had been reached.

It seems to be advisable to use the two-bearing type of generator, either bolted to the engine frame or mounted with three-point suspension in the chassis. In each case a flexible coupling should be used between the engine and the generator. It would be highly desirable if the engine and generator designers could get together and develop a design in which the generator and engine are mechanically more suited to each other, resulting in an improved and unified design.

To the advantages of gas-electric drive, as given by Mr. Atwell, can be added decreased maintenance, as shown by actual operating statistics, and decreased platform wages, due to the higher schedule-speed, which results in fewer hours per mile, and fewer vehicles for a given number of daily vehicle-miles.

FEWER VEHICLES FOR THE SAME WORK

In the disadvantages, Mr. Atwell has listed increased first cost. A gas-electric motorcoach having the same engine-power and seating-capacity as a mechanical-drive vehicle is heavier and undeniably costs more. However, the increased schedule-speed and decreased time of maintenance of the gas-electric results in fewer transportation units to give the same service; and studies have disclosed that the first cost of the total number of gas-electric vehicles required may be only from 2 to 3 per cent greater.

Little has been said about the economy of gas-electric drive, which is, after all, the real reason for its development. The greater weight and cost of a gas-electric coach of given capacity is of importance only as it reflects in the annual cost of operation and the earning power. Comparative statistics of operation in city service indicate that, after all operating charges, taxes, depreciation and interest on the investment have been paid, there is a substantial saving in favor of the gas-electric coach.

It is reported that more riders are attracted by changing from mechanical to electric drive; increases of

[11] M.S.A.E.—Chief engineer, American Car & Foundry Motors Co., Detroit.

[12] General Electric Co., Chicago.

20 per cent are not uncommon. More riders, with the resultant increase in revenue, combined with lower operating expenses and fixed charges, indicate an earning power for gas-electric drive well above that for mechanical drive.

QUESTION:—What are the weights and horsepower ratings of the smallest and largest units now being considered?

MR. ATWELL:—Most of the vehicles are of about 30-passenger capacity, weighing about 16,000 lb., without passengers. The electric equipment adds about 2000 lb. The eight-wheel vehicle to which reference was made in my paper weighs about 22,000 lb., with the electric equipment. There are so many variables entering the question of horsepower that it is difficult to assign horsepower ratings to units such as these.

QUESTION:—How is the gas-electric vehicle controlled?

MR. ATWELL:—All the driver has to do is to take hold of the steering wheel and step on the throttle, and the vehicle starts. There is a drum controller, but it is not for the same purpose as the controller on a street-car; it is used for reversing the direction and for braking. On a vehicle having two motors, it can also be used to provide a series connection for ascending grades, in place of the parallel connection, thus giving greater tractive effort. In ordinary driving, the accelerator pedal is the only control required for the speed.

AVOID EXCESSIVE ENGINE-SPEED

LOUIS P. KALB[13]:—To the engine man, one of the most attractive possibilities of the gas-electric vehicle is its ability to maintain high average vehicle-speeds without excessive engine-speeds. Considering the engine speeds required to enable a mechanical-drive motorcoach to maintain its scheduled speed, it is a wonder that the engines last as long as they do. I do not know that this possibility has been utilized to its fullest extent; but experimenting has been done, and all engine men would like to see progress along this line.

A few years ago there was an idea that the electric drive would permit the use of smaller engines, but I am thankful that this idea was not taken seriously. If it requires 100 hp. to propel a vehicle at a certain speed, the same power will be required with either type of transmission. If anything, the electric drive might require more power because of its reduced efficiency.

The discrepancy between methods of rating gasoline engines and electric motors has led to some confusion and misunderstanding, but I believe that Mr. Butler did not intend to imply any attempt to mislead. When an engine power-curve is issued, it represents the actual power-curve of the engine. We know that the fan, especially a 24-in. fan, may consume as much as 8 or 10 hp. There also are electric units to consider. I have had contact with both Westinghouse and General Electric engineers and I find that both companies are attacking this problem in a most thorough and scientific way.

BOUNDARY OF THE ELECTRIC-TRANSMISSION FIELD

C. FROESCH[14]:—There is no question that the smoothness of the electric drive and its uninterrupted acceleration renders it more suitable than the mechanical transmission for city operation. Acceleration tests have shown that, up to 1000 ft., the electric drive is superior; in other words, a gain is obtained if traffic conditions call for five or more stops per mile.

In a recent check on mechanically driven motorcoaches the total time lost in shifting, during acceleration from a standstill to a running speed of say 20 m.p.h., amounted to 5 to 7 sec. This loss the electric drive eliminates; and, while its efficiency is considerably lower than that of the mechanical transmission at the start, the average horsepower at the wheels during the acceleration period is greater.

The efficiency of the electric drive, as now designed for motorcoaches, is very low at high ampere-loads such as are met with in starting in deep snow or sand. In a paper[15] which I presented before the New England Section of the Society, a tabulation of dynamometer tests is shown which reveals that the over-all efficiency of the electrical units drops as low as 50 per cent compared with 82 to 85 per cent for the mechanical drive. Some recent improvements have bettered this condition and offset it by obtaining better fuel economy, because of working the engine at wide-open throttle most of the time and taking advantage of the best portion of the fuel-economy curve. I understand that a large operator has been able to obtain 20 per cent more ton-miles per gallon with a gas-electric than with a mechanically driven motorcoach.

I do not agree with Mr. Atwell when he says that it is necessary to apply a small cumulative series-winding to prevent an undue fall of voltage at high ampere-loads. It is possible to design a straight shunt-wound machine to prevent this. While the characteristic curves might show that it is required for stability, it is not absolutely necessary, because the engine that drives the generator is essentially a constant-torque prime-mover. Its speed will increase with a decrease in generator-torque demand, and vice versa, until a condition of balance exists. It is needless to say that a characteristic which will permit constant engine-speed at wide-open throttle to secure maximum fuel-economy would prevent slowing down on grades or while accelerating, and improve over-all performance. To obtain this most-desired characteristic with present-day engines, a variable resistance usually is inserted in the shunt field.

TEASER FIELD FROM THE GENERATOR

Recently we have tried successfully to eliminate the battery altogether from the teaser-field circuit by connecting the latter in series with the lighting generator of the engine. At low engine-speed there is no current-flow through the teaser field, and the lighting-generator voltage builds up rapidly as the accelerator pedal is pressed, thus energizing the teaser field immediately. When the power-generator voltage reaches the value of self-excitation, the teaser-field circuit is opened to relieve the load on the lighting generator and permit it to charge the battery. Tests have shown that there is no appreciable lag in starting, as compared with a battery-energized teaser-field.

Electric braking is one of the necessary evils of gas-electric-drive coaches and is a problem that should receive a great deal of consideration. We speak of the smoothness of acceleration and the ease of its reaction on the rest of the motor-vehicle, but more damage can be done by the sudden application of the electric brake, by some one who is not able to use it, than by misuse of

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[13] M.S.A.E.—Assistant chief engineer, Continental Motor Corporation, Detroit.

[14] M.S.A.E.—Engineer, gas-electric bus design, International Motor Co., Long Island City, N. Y.

[15] See THE JOURNAL, September, 1927, p. 268.

the clutch in a mechanical drive. I say that it is a necessary evil because such a brake often is requested by the purchaser. This brake was designed primarily to offset the lack of engine braking when running downgrade, and it is highly efficient for this purpose. However, if it is to be used often, the electric motor should be 20-per cent larger. The elimination of electric braking would simplify the electric drive considerably and would permit substituting for the present controller an ordinary double-throw double-pole switch for forward, neutral and reverse. The added weight of the electric drive and the inertia of its motor armature throw about 20-per cent more burden on the friction brakes of the vehicle.

For vehicles not exceeding 10 to 12-tons gross weight, I believe the single-motor drive is superior. For heavier installations the dual drive is necessary, because of ground clearance and limitation of floor height. Of course, the principal advantages of the single-motor drive are lightness; simplicity, which means reliability, to a great extent; and the use of a conventional rear-axle to keep unsprung weight as low as possible. By inserting a brake in the drive, use can be made of the differential to equalize braking effort on the rear wheels, especially on slippery pavements. This cannot be done with a dual drive, because, when the vehicle is being braked, no power flows through the motors, and locking of one side is possible.

A Combined Motor-Generator Unit

The application of the electric drive has reached a point where it must stand or fall on its economic merit. Its inherent advantages have made it popular with passengers, but some disadvantages must be overcome before it can win completely the confidence of the operators. Some motorcoach owners regard it with skepticism because of its complications. For this reason it is hoped that it may be possible in the near future to design a drive with generator, motor and controller built into one unit and integrally wired, to permit mounting in the chassis as a unit. This will also make possible a reduction of weight and cost. With a combination drive, the motor cooling fan could be driven by the generator, so as to have good cooling at low motor-speed and save horsepower at high speed.

Further study should be given to the windings, to improve the efficiency. Electric drives today weigh from 230 to 275 lb. per ton of chassis and body weight, and it is hoped that a more liberal use of improved materials will help to reduce this in the future.

I should like to ask Mr. Atwell what lubricants are recommended for motor and generator bearings.

Mr. Atwell:—Series turns on the generator are not always necessary to maintain the voltage when the current is heavy. There are other ways of accomplishing the same end. The object of the voltage regulation is to control the horsepower so that it will not vary too much at a certain speed with different currents and, as a result of that, to obtain a relatively flat speed-regulation of the generator and engine over the operating range. The ideal would be to have a certain engine-speed, selected as the most economical by the engine builder, held constant over the entire range of operation. This cannot be done without additional complications that do not seem desirable on a motorcoach, although field regulators have been applied to railway-car generators to do almost exactly that.

The severity of braking, to which reference has been made, must have been secured by connecting the motors in reverse. With this arrangement the operator can cause a severe jolt by pressing the accelerator pedal too hard. Dynamic braking, with variable resistances connected across the motors, is very smooth.

Combining the two electric-machines in a single unit might be desirable in certain types of motorcoach, but I believe that the present tendency shows the advantage of making a complete mechanical separation between the powerplant and the driving wheels.

For the roller-bearings on the armature of the motor and generator, we find that the best lubricant is that sold as "ball-bearing grease" by various lubricant manufacturers. The design of the machine is such that this grease is retained in the bearings for a long time; and dirt, which is the usual cause of bearing failure, is kept out.

Engine Speed During Vehicle Acceleration

Mr. Brumbaugh:—When the driver presses the accelerator pedal of a standing gas-electric motorcoach, the engine immediately goes to a speed of about 2000 r.p.m. It then develops its maximum power at a time when the efficiency of the electrical units is the lowest. As the vehicle speed builds up, the engine slows down. It is at about 1400 or 1500 r.p.m. at half the maximum speed of the vehicle, then speeds up again as the vehicle speed rises. This means that an engine must develop nearly 75 or 80 per cent of its maximum power all the time, and that requires an extremely rugged engine.

One of the advantages of the electric transmission is in the wonderful braking action secured from the engine through it. Also, the gas-electric vehicle unquestionably is more durable than a vehicle with mechanical transmission. Evidently this is why the Philadelphia Rural Transit coaches are held under equipment trusts on a 10-year basis, an arrangement that would be difficult to make with mechanical-drive chassis.

Just as the manufacturers of electrical equipment doubt the curve of the engine man, so we have to take with a grain of salt the published curves on electrical efficiency. Efficiencies as high as 92 per cent are not always realized. I have seen an engine develop more than 100 hp., with only 45 hp. coming from the motor shaft; the difference was expended in warming up the atmosphere through the carefully arranged ventilating-ducts of the motor and the generator. In spite of this, we believe that the gas-electric transmission has a very definite and useful field.

One thing, sometimes overlooked by chassis engineers, is the remarkable susceptibility of the human body to horizontal acceleration. Engineers try very hard to design springs and snubbers to prevent the passengers from bouncing up and down, but let them be yanked this way and that until they are blue in the face. The gas-electric drive helps in that connection.

The main argument in favor of the gas-electric coach is that it releases the right arm of the driver. If the need for an additional right arm means adding another man to the crew, there is a great saving in making it possible for the driver to collect the fares, make change and issue transfers. The Philadelphia Rural Transit Co. is operating double-deck coaches with one man. Do you think that it would be possible for a driver with a mechanical transmission to handle a 60-passenger coach alone?

QUESTION:—Is the gas-electric system applicable to passenger-cars; and, if not, what besides weight are its disadvantages?

MR. ATWELL:—I believe that electric transmissions were applied to passenger-cars long before they were considered for motorcoaches; notably, the Entz transmission[16], which was used on the Owen magnetic car. I do not know the exact reason why this system is not now in use, but I imagine it is because of the complication of the control. This transmission required a controller on the steering column, and it provided for the charging of the storage battery and acted as a starting motor. These functions are now accomplished by such well-standardized units that it is not worthwhile to complicate the electric transmission with them. Aside from weight, the chief handicap probably is the first cost.

THE DISCUSSION AT CHICAGO

J. C. A. STRAUB[17]:—It is necessary to keep down as much as possible the weight of a gas-electric installation. Making the generator in a single unit with the engine helps in this by reducing bearing weight and flywheel weight, which can be done if the coupling is not too flexible to allow the armature to act as a flywheel.

Two motors in tandem seems to me to be the best arrangement, as the friction is less in a single worm than in two worms, and the heavier propeller-shaft required is less likely to whip.

J. CHUCAN[18]:—What is the need of the battery teaser-field in units that ordinarily are complete in themselves without a battery; why cannot the battery be eliminated?

C. A. ATWELL:—We have no units in which the battery field is not provided. It seems to be necessary, because it greatly increases the rate of pick-up of the generator when the operator steps on the accelerator pedal, which is an important factor. The field builds up very much quicker than it would from residual magnetism alone.

W. C. BECKER[19]:—How much is the engine life increased with electric drive?

MR. ATWELL:—The increased life of the engine results mainly from the facts that it is operating under full load most of the time and that the engine revolutions per vehicle-mile are considerably less, because the engine drops to idling speed as soon as its power is not required. No definite figures are available yet, because the majority of the gas-electrics have been in use not more than 3 years, and that has not been long enough to wear them out.

R. D. HARRISON[20]:—During the last year or so we have been making a detailed study of the application of gas-electric transmissions on mechanical-drive motorcoaches and have centered this study around a fleet of 2000 vehicles, 1000 having mechanical drive and the other 1000 having gas-electric drive. These coaches are being operated by various companies throughout the United States. To make a fair comparison, all the vehicles were put on a basis of comparable schedule, weight and power. As a result of our study we have found the following:

(1) The present tendency among operators is to depreciate their mechanical-drive motorcoaches over a period of 5 years and their gas-electric motorcoaches over a period of 8 years.

(2) The chassis and body maintenance on gas-electric coaches is approximately 1¼ cents per vehicle-mile less than that of mechanical-drive vehicles.

(3) Gas-electric motorcoaches maintain a 10 to 15 per cent faster schedule than similar mechanical-drive coaches in the same service. This is because the horsepower of the engine is used to better advantage and continuously throughout the accelerating period, and because the operator is relieved of the duty of shifting gears. It follows that, disregarding fractions, usually seven gas-electric coaches can replace eight mechanical-drive coaches.

(4) The availability of mechanical-drive motorcoaches is from 80 to 85 per cent, and that of gas-electrics is from 90 to 95 per cent. This means less spare equipment required and reduces the investment in the fleet.

[16] See TRANSACTIONS, vol. 11, part 2, 1916, p. 502.

[17] M.S.A.E.—Assistant chief engineer, motor-truck and coach engine development and design, International Harvester Co., Chicago.

[18] M.S.A.E.—Chief engineer, Mercury Mfg. Co., Chicago.

[19] A.S.A.E.—Assistant superintendent of utility department; superintendent of bus service, Chicago Surface Lines, Chicago.

[20] General Electric Co., Chicago.

Highway Construction Through Gasoline Tax

TAXATION of gasoline in 1927 produced a total net revenue of $258,966,851, according to information collected from State authorities by the Bureau of Public Roads of the Department of Agriculture. Of this, $182,095,503 was available for the construction and maintenance of State highways under the supervision of the State highway departments and $55,440,161 was apportioned to counties for local road purposes, including the payment of interest and retirement charges on highway bonds. The yield of the tax constituted an important contribution to the revenue that is expended upon highway construction and maintenance.

The tax was collected in every State but Massachusetts and New York, the rate ranging from 2 to 5 cents per gal. The returns indicate an increase in gasoline consumption over 1926 in all but two States. Including estimates for the two States in which the tax was not imposed, it is indicated that 10,596,000,000 gal. of gasoline was used by motor-vehicles during the year, an increase of 8.2 per cent over 1926. The average consumption per motor-vehicle was 458 gal.—*Motor Travel.*

Automotive Research

Research Progress Shown

THE various meetings of the Research Committee and its subcommittees held at Quebec during the Summer Meeting furnished the occasion for much discussion indicating active accomplishment in the research projects of the Society and for the forming of a number of interesting plans for carrying them to further achievement. Some of the material presented was in the nature of progress reports of investigations not yet carried forward to the point where publication of results seems advisable; a number of the topics, however, seem to be of a nature to be of interest to other members of the Society either engaged in research themselves or desirous of keeping in touch with the search being made by others for new knowledge in the automotive field. In some of its undertakings, the Research Committee is seeking the cooperation of members of the Society.

Simple Head-Lamp-Glare Testing Instrument

Dr. H. C. Dickinson, at the meeting of the Headlight Subcommittee, described a simple inexpensive device that he has arranged for his car. Its purpose is to determine the number of times the light from an approaching car exceeds, is less than, or is equal to, a fixed value. This device can be fastened to a car in an inconspicuous way and used in the course of ordinary driving.

Glare statistics which would result from the use of this device would be of great value, not only because of the general bearing of glare on the headlighting problem, but because of the difficulty of accurately estimating the importance of this factor. Whether glare or insufficient light causes more discomfort in night driving is a disputed question. A driver will also find it hard to judge when a light is glaring, as so many psychological and other factors enter into his appraisal, aside from the actual amount of light coming from the approaching car. That half of the glare is caused by irritation, as one observer asserts, is a statement that may not be universally accepted, but the general sentiment that the driver's mental condition influences his estimate will undoubtedly be subscribed to whole-heartedly.

The device arranged by Dr. Dickinson will give an accurate measurement and, since its use does not involve a special test set-up, the statistics obtained represent the conditions encountered in average night-driving. Dr. Dickinson has made interesting observations with it, and at the meeting members of the Research Committee and all others interested in headlighting were urged to contribute to the further knowledge of this phase of the problem. To be of the utmost value, such data should not only include a considerable volume of observations but should cover a wide range of territory.

Essentially, the device is a small portable photometer fashioned from two pieces of oiled paper enclosed in a cardboard frame, in all about 2 in. square, upon which a small flashlight is trained. The photometer unit is pasted to the windshield of the car in the line of oncoming light and the flashlight is conveniently attached. Connected in series with the flashlight is a small rheostat by means of which the current may be varied at will. The apparatus is readily calibrated. Readings are obtained by observing whether the light from an oncoming car exceeds, is less than, or is equal to, the amount of light for which the photometer has been calibrated. The number of readings under, over, or equal to this intensity are recorded by conveniently located hand-counters. A rough estimate places the cost of the parts to make the apparatus at about $10.

Demonstration Meeting To Check Test Results

The desire to obtain observations representing divergent viewpoints, which was the incentive prompting the development of this instrument, was the mainspring of a plan formed at the meeting. A report has been made of the headlight research being conducted at the Bureau of Standards under the technical direction of the Research Committee, with funds provided by the National Automobile Chamber of Commerce. This research, which is of fundamental nature, is directed toward ascertaining by road tests supplemented by laboratory experiments what light distribution will best satisfy the requirements of night driving. The desirability was discussed of having the results obtained checked by a more divergent group of observers than has been available in the investigation, and tentative plans were made for a demonstration meeting at which this could be done.

Arrangements were suggested for having partake in the demonstration a considerable number of observers who would not be familiar with the details of the lighting distributions being tested and would therefore have the mental attitude of the ordinary driver on the road rather than that of the professional investigator. The superiority or inferiority of the beam patterns tried will have to be sufficiently pronounced to impress a driver not necessarily on the alert for such changes. To increase the resemblance to practical conditions, the lighting will be provided by head-lamps placed on the cars in the conventional way instead of by the four-headlamp test set-up used in the investigation. Runs will be made over roads representing, so far as possible, all varieties of surface likely to be encountered. Much information of practical interest is expected to be developed as the outcome of this meeting.

Cooperation in Riding-Qualities Research

The efforts of Prof. J. M. Nickelsen, of the University of Michigan, Chairman of the Subcommittee on Wheel Alignment, to perform the mission assigned to the Subcommittee have met with a gratifying response from the members of the Subcommittee, both individually and as representatives of car and tire manufacturers. At the January meeting of the Research Committee, B. J. Lemon urged that some investigation be made to throw light on the subject of wheel alignment. Following his suggestion, the chairman was authorized to appoint a subcommittee to determine the state of knowledge on this subject, to gather such data as are available and to assemble and digest them for the informa-

tion of all those interested. Professor Nickelsen, in outlining the problem before the Subcommittee, pointed out that the consumer, who is the ultimate judge of car performance, is interested in wheel alignment as it relates to front-end control in light steering, holding the road, shimmy and wabble, and tire wear. To throw light on these features of car performance, he suggested that a study be made of toe-in, camber, caster and steering-knuckle-pivot inclination. Such a study, he thought, should include the conditions on both new cars and cars that have seen some service.

Contributing to the carrying out of Professor Nickelsen's program, O. T. Kreusser, director of the General Motors Proving Ground and a member of the Subcommittee, has volunteered to make measurements of the angles of the enumerated items on all new cars entering the General Motors Proving Ground and to repeat such measurements after the cars have been run several thousand miles. This information will then be plotted against the steering ability of the car, its general ability to hold the road, shimmy and wabble, and the over-all front-wheel tire-wear. Mr. Lemon has been active in the collecting of information for the Subcommittee's purpose.

Purdue To Make Riding-Qualities Research

An evidence of the extent to which colleges and universities are ready to cooperate with the Society in its research work was given at the meeting of the Riding-Qualities Subcommittee. Prof. H. M. Jacklin, of Purdue University, told the Subcommittee that the services of Prof. M. J. Zucrow, at the engineering experiment station, were available for the study of some project that might be selected as of particular interest. It was thought that some topic connected with riding-qualities might offer the most fruitful field for such work. In accordance with the wishes of the Subcommittee, Professors Jacklin and Zucrow will prepare a tentative program for their proposed research, to be considered by the Research Committee at a meeting to be held early in the autumn.

An attempt will be made to secure the cooperation of other universities in the study of the psychological phase of the riding-qualities problem. The time is now ripe, it is felt, for some attempt to establish for human beings a curve representing sensitivity to shocks and vibrations such as are likely to be encountered in motor-car riding, since recent development work has made available accurate instruments which can easily be used. As the problem includes elements of psychology, physiology and engineering, it is peculiarly suited to study by universities which combine the personnel and the facilities for study of all three subjects.

After considering these points, the Subcommittee made arrangements for circularizing university departments of psychology and physiology and for personal visits to some of the more interested for the purpose of collecting all available information on the physiological and psychological effects of vibrations and motions within the range of automotive driving.

Theoretical Aspects of Detonation

Keeping pace with current problems, the Cooperative Fuel-Research Committee is devoting considerable effort to a study of detonation, in addition to its work on gasoline volatility and engine acceleration, which was covered in papers presented at the Research Session of the Summer Meeting. At a meeting of the Fuels Subcommittee, which represents the Society in the cooperative project, the other participants in which are the National Automobile Chamber of Commerce and the American Petroleum Institute, a number of reports were made on the progress of the various investigations that are under way.

Of particular interest is the study now being made of the laboratory work that has been done bearing on the fundamentals of the relation between fuel characteristics and detonation. This project was initiated at the Feb. 14 meeting of the Cooperative Fuel-Research Committee, when the Bureau of Standards was requested to make a survey of the literature and current unpublished work on the theoretical aspects of detonation and to report what had been definitely established and what might be done to fill in the gaps in the existing work.

As a first step, a review has been made of the literature. Four phases of the general problem have been considered: (*a*) ignition temperatures of liquid fuels, (*b*) ignition temperatures of gaseous fuels, (*c*) ignition by adiabatic compression, and (*d*) oxidation of hydrocarbons and hydrocarbon fuels. A bibliography covering these topics has been prepared and the more important articles have been read and their contents summarized.

It is contemplated that at the next meeting of the Cooperative Fuel-Research Committee a report will be presented which will include a summary of the work done to date and the facts that have been conclusively established, give an outline of those phases which have been overlooked or on which the experimentation is incomplete and offer suggestions as to specific problems on which work needs to be done. For this purpose, the Bureau of Standards needs, in addition to the information gained from the literature, experimental data bearing on those projects that have not reached publication but that still represent substantial contributions to the study of detonation. The Bureau has communicated with academic and industrial laboratories in this Country to ascertain what current work is being done on problems related to detonation, and has received information from a considerable number of these institutions. In addition, the Bureau is anxious to have the cooperation of all those in touch with research in progress on this subject, and asks that such persons make available the information they have or tell the Bureau of institutions from which additional data should be sought. With such assistance, together with the knowledge gained through the literature, it is the intention to map out the research covering the field of detonation in such a way that the unexplored territory can be clearly seen. Any future work done by the Cooperative Fuel-Research Committee on the theoretical aspect of detonation will therefore be in virgin ground, with an assurance against any wasteful duplication of effort.

Side by side with the theoretical research has gone an investigation of practical aspect, that is, the survey of the detonation characteristics of fuels available to motor-car users. A similar investigation was made during 1927. The purpose of the recent repetition was to make information on current conditions available and to fix a second point on the curve showing the tendency in fuel characteristics.

Standards Division Reports Approved

FORTY of the reports as submitted by eight divisions of the Standards Committee were approved for submission to letter-ballot on adoption at the regular Standards Committee Meeting held in Quebec, Canada, on Tuesday, June 26. Fifty-five members and guests of the Committee were in attendance to consider and pass on the reports of the Aeronautic, Electrical Equipment, Engine, Iron and Steel, Lighting, Lubricants, Passenger-Car, Production, and Tire and Rim Divisions.

All of the reports, with the exception of that on Spark-Plug Taps, were printed in the June, 1928, issue of the S.A.E. JOURNAL as originally approved by their respective divisions. As the reports were passed upon by the Standards Committee, however, typographical errors were corrected or modifications were made in the reports in a number of instances, due largely to reconsideration by the Divisions since the reports were printed. Such corrections and modifications are referred to in the following account of the action taken on the reports. The only report referred back to its originating Division for further consideration was that of the Lubricants Division on Crankcase Lubricating-Oils.

Vice-Chairman W. R. Strickland presided at the meeting and, notwithstanding the number of reports presented was larger than usual, the entire program was completed in a record short time.

The action taken by the Standards Committee on the several reports was reviewed and approved by the Council of the Society at its meeting on Thursday afternoon, June 28, and at the adjourned Business Session of the Society members in the evening of the same day, when the approved reports were ordered to final letter-ballot by all voting members of the Society for adoption in accordance with the recommendations of the Division on each report.

The letter-ballot will be returnable and counted on Friday, Aug. 31, immediately after which the reports so approved will be prepared for printing in HANDBOOK form in pamphlets that can be inserted in the 1928 issue of the S.A.E. HANDBOOK and incorporated in the next issue of the HANDBOOK, which will be printed next March.

Report Referred Back to Division

LUBRICANTS DIVISION

CRANKCASE LUBRICATING-OILS

This report proposed the addition of a footnote to the present S.A.E. Recommended Practice printed on p. 470 of the 1928 edition of the S.A.E. HANDBOOK. It referred to the viscosity numbers to be used in connection with prediluted oils. It was felt by the Standards Committee Meeting that the proposal is questionable and should be given further consideration by the Division.

THE DISCUSSION

H. J. SALADIN[1]:—The Lubricants Division felt there should be some means of designating the viscosity of prediluted oil. The work done by the Bureau of Standards and data given in a paper entitled A Suggested Remedy for Crankcase-Oil Dilution, by R. E. Wilson and R. E. Wilkin, published in THE JOURNAL in January, 1926, indicated rather definitely that the viscosity of oil after equilibrium would be the same whether a diluent was or was not added. The Division thought, therefore, that this recommended note would be the best way of designating the viscosity of the prediluted oil.

VICE-CHAIRMAN W. R. STRICKLAND[2]:—It seems to me that this would be a double standard for the customer. He would not know whether the oil he gets is a diluted oil or not, or what its viscosity is.

MR. SALADIN:—The viscosity of the oil certainly would be the same after equilibrium.

J. C. GENIESSE[3]:—Should there not be some designation, for instance a letter *D*, after the number so the customer will know he is getting an oil that is less viscous than an undiluted oil?

MR. SALADIN:—The Division gave that point consideration and it was the opinion that in general it would be better if there were no special designation. Such a designation would mean that a car-maker would have to use a double designation if he wanted to recommend prediluted oil as well as an oil that was not prediluted.

K. L. HERRMANN[4]:—To classify prediluted oils in the same way as oils that are not prediluted seems to be unreasonable.

R. E. WILKIN[5]:—The idea of applying the S.A.E. Viscosity-Numbers to lubricating oils was to specify the body of an oil to be put into the crankcase of an engine. If you use the S.A.E. Viscosity-Number corresponding to a prediluted oil, you are in the same way specifying the same grade of oil to be used. For instance, oil of S.A.E. Viscosity-Number 30, whether prediluted or not, will have the same viscosity in the engine and will operate the same way. The S.A.E. Viscosity-Number should correspond to the base oil and not to the prediluted oil, because we are interested in the body of the oil in the engine during the major part of its operation.

MR. STRICKLAND:—The difference is that when the customer buys "4 qt. of oil," he may get 3 qt.

MR. WILKIN:—That is something to be solved by the people marketing the oil. This recommendation relates to using a number for the oil which will specify to the customer what oil he is getting.

A. J. SCAIFE[6]:—When the S.A.E. Viscosity-Numbers were adopted, we had a warm argument on whether they should be S.A.E. numbers or the letters S.A.E. should be used after a number, because of the trouble that might result through the "gyp" dealer. I wonder if there is any danger, in this recommendation, of having oils that are re-refined or reclaimed, or doctored with kerosene or something else, and sold on the market under an S.A.E. number.

MR. WILKIN:—The S.A.E. Viscosity-Numbers apply only to the body of the oil. Black oil might be washed and sold under an S.A.E. number and be within the requirements of this recommendation, but it is the responsibility of the people who market the oil to put quality into it. The S.A.E. numbers are not a measure of quality.

Reports Approved

The reports as approved are as follows, the reference after each subject indicating the status of the report and the page of the June issue of THE JOURNAL on which it is to be found. The corrections or modifications made in the

[1] M.S.A.E.—Assistant manager, lubricating department, Standard Oil Co. of Indiana, Chicago.

[2] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

[3] M.S.A.E.—Research chemical engineer, Atlantic Refining Co., Philadelphia.

[4] M.S.A.E. — Consulting engineer, Studebaker Corporation of America, South Bend, Ind.

[5] M.S.A.E.—Automotive engineer, lubricating department, Standard Oil Co. of Indiana, Whiting, Ind.

[6] M.S.A.E.—Chief field service engineer, White Motor Co., Cleveland.

reports at the Standards Committee Meeting are included under the respective titles. The Aeronautic Division report is preceded by statements by Chairman Edward P. Warner and by Flight-Lieut. A. Ferrier, of the Canadian Air Force.

AERONAUTIC DIVISION

EDWARD P. WARNER[7]:—This is a significant meeting for the aeronautic standardization activities of the Society, which have been revived on a considerable scale. There seems to be no reason why these activities should not now be continued. We are celebrating our return to the arena of standardization effort by presenting a considerable number of recommendations. The first is for the standardization of Aircraft Storage-Batteries. The Battery Subdivision intends to give consideration to alternative forms, shapes and sizes which may be adopted to supplement those here listed. The proposal for Tail-Skid Shoes standardizes only the means of attachment, making it possible to use shoes of varying form interchangeably on the same skid so that a damaged shoe may be replaced by one originally designed for another airplane or another service. The proposed standards for Aircraft Bolts and Nuts, Plain Hexagon-Head Bolts and Plain Hexagon-Nuts, for Castle Hexagon-Nuts, Ball Hexagon-Head Bolts and Nuts, Eye-Bolts, Flat Washers, Pulleys, Rigid Terminals, Shackles and Turnbuckles all follow essentially the standards already adopted by the Joint Army and Navy Conferences and now in use by the Government services. Except for certain minor modifications where they seem desirable for fittings in commercial use that are not likely to be required for military purposes, the AN Standards have been followed.

The recommendations for Generator Mountings, Fuel-Pump Mountings and Engine-Starter Mountings were prepared by a special Subdivision on Engine and Accessory Mountings and have been approved as presented here by the Aeronautic Division. In the past, the mounting of navigating and engine instruments on the instrument-board has been subject to much variation of instrument dimensions and of form of mounting, but it has been found that instruments now being made conform in general to certain dimensions when designed for a given purpose, or at least that with but little effort existing instruments can be made to fit a mounting built in accordance with the dimensions here listed for tachometers, air-speed indicators, pressure-gages, altimeters and thermometers.

The standardization of crankshaft or Propeller-Shaft Ends for aircraft engines, which will permit of interchangeability of propellers on engines of differing size and design, has been the subject of very careful study by the Division for several months. We wish, however, to amend this recommendation in certain particulars, the amended form having been approved by a mail vote of the Division members. The recommended changes in general are that the propeller-hub shaft-end standard be divided into two parts, one for tapered ends and the other for splined ends. The tapered-end shafts Nos. 1 and 2 are to remain as presented. The No. 3 splined shaft-end should be changed to a 16-splined form and shortened by 1 in., and given the number 30, the No. 4 splined end to be specified as No. 40. We also recommend that another splined end of smaller size suitable for engines of low power, to be designated as No. 20, be added, making a total of two tapered and three splined shaft-ends as alternatives for engine manufacturers to use.

The matter of international standardization presents itself for the aeronautical industry in a somewhat different form from that in which it appears to the builders of highway vehicles and it is a question of particular importance among those whose guests we are this week. As the Canadian Government and Canadian commercial operators are obliged to make use of British and American-made airplanes and airplane engines more or less interchangeably, they are very desirous that the degree of interchangeability be as great as possible. This presents a definite problem of engineering to work toward international standardization of such things as wheels, propeller shaft-ends, and other points of assembly, assembly of accessories and major components of aircraft. Flight-Lieutenant Ferrier, of the Canadian Air Force, is here today representing Wing-Commander Steadman's division, Commander Steadman being the head of the technical work of the Canadian Air Force and the Canadian Air Board. The Chairman has invited Lieutenant Ferrier to speak briefly on the Canadian position on standardization in aircraft.

FLIGHT-LIEUT. A. FERRIER[8]:—The work that is now being done in the United States on standardization of parts for aircraft and aircraft engines is of considerable interest to aeronautical engineers in Canada but unfortunately this work does not go sufficiently far to meet Canadian requirements. In Canada a very large proportion of the equipment used for aviation purposes is of European manufacture and therefore any standardization, to be of real value to Canada, should be carried out internationally. In the Department of National Defense we use a large number of radial engines of about 200 hp., and usually provided with all-metal propellers. The American engines have a very different propeller-shaft from the English engines of similar power, and therefore we are forced to carry two different kinds of propeller-hub to suit the two engines. If some international agreement could be had on the design of propeller shaft-ends, it would greatly facilitate the carrying of spares for operational purposes.

Another subject for consideration is the standardization of wheels. There are wide differences between the standards used in the United States and in Great Britain. Also, in the wheels manufactured in the United States there is a great difference, relating to the methods of operating the brakes, for example. This means that only one type of wheel can be used on a given aircraft. This condition is often aggravated because subsequent aircraft made by the same manufacturer do not always have the same type of wheel and brake system, so that, although spares may be carried for one aircraft of a given make, there is no way of guaranteeing that the same spares will suit the next aircraft made by the same manufacturer. This varying of wheel dimensions is causing considerable trouble at present.

AIRCRAFT STORAGE-BATTERIES

(*Proposed S.A.E. Standard, p.* 697)

TAIL-SKID SHOES

(*Proposed S.A.E. Standard, p.* 698)

AERONAUTIC BOLTS AND NUTS

(*Proposed Revision of Present S.A.E. Standard, p.* 698)

In the table for Castle Hexagon-Nuts, the following footnote was added for the bolt-size *A*:

Note.—Finished sizes include plating or protective coating.

In the table of Plain Hexagon-Head Bolts, the tolerance D^2 for the No. 8 bolt-size should be + 0 — 0.0050, and dimension *E* should be 15/64 instead of 7/32. The dimension *E* in the cut should extend to the end of the thread instead of as shown.

In the table of Plain Hexagon-Nuts, the dimension 9/16 in the second column under heading N^1 for the No. 10 size should be 9/64.

In the table of Ball Hexagon-Head Bolts and Nuts, the heading of the fifth column should be *C* instead of *D*. The minus tolerance for the bolt diameter of the No. 8 size should be 0.0050 instead of 0.0030. The minimum tensile-strength for the ¼-in. size should be 4070 instead of 3070 lb. Dimension *B* for the 7/16-in. size should be ⅝ instead of 11/16. The phrase "the angle of bend to be through 35

[7] M.S.A.E.—Assistant Secretary of the Navy for Aeronautics, City of Washington.

[8] Canadian Air Force.

RIGID TERMINALS

Hand	Tensile-Strength, Minimum	Thread	*B*	*D*	*F*	*G*	*H*	*I*	Drill *A*	Drill for Threads	*M*	*S*	*T*	*Y*	*Z*
L. H.	20,200	9/16-18	3.125	0.563	0.922	0.453	0.375	0.094	0.578	0.5062	0.796	1.375	1.625	1.000	1.063
R. H.															
L. H.	24,700	5/8-18	3.375	0.625	1.032	0.516	1.500	0.094	0.640	0.5687	0.875	1.500	1.750	1.125	1.188
R. H.															

deg." was added to the last sentence of the footnote reading "Bolts shall stand cold-bending in the plain part, etc., etc.," and the footnote reading "Bolts conforming to these specifications shall be marked with a triangle as shown" was changed to read "Bolts conforming to these specifications shall be marked in some distinctive manner where shown."

SMALL AIRCRAFT-FITTINGS

(*Proposed S.A.E. Standard, p.* 701)

In the illustration for Eye-Bolts, the radius under the head should read radius 0.010 + 0.005, — 0.000 in. In the table the minus tolerance on the bolt diameter for the largest size should be 0.0082 instead of 0.0072. The minimum tensile-strengths for bolt diameters 0.3125 and larger should be respectively 6550, 10,000, 13,620, 18,580 and 23,600. The following phrase was added to the last sentence of the footnote reading "Bolts shall stand cold-bending in the plain part," etc.: "the angle of bend to be through 35 deg."

The first sentence of the footnote on marking is changed to read, "Bolts conforming to these specifications shall be marked in some distinctive manner where shown."

In the illustration for Rigid Terminals, the dimension *T* should extend to the center of the hole rather than to the edge of it. Dimension *H* for the 15,500-lb. size should be 1.188 instead of 1.183. The dimensions for a 20,200-lb. and a 24,700-lb. size were added to the table and these are printed at the top of this page.

In the illustration for the Turnbuckle Cable-Eye, the note reading "the tolerance specified for pitch diameter," etc., was deleted and the plus tolerance for dimension *Z* was changed from + 0.051 to 0.031. The minus tolerance on dimension *E* for the 12,500-lb. long cable-eye end should be — 0.0072 instead of — 0.0000.

The following note was added to the Turnbuckle Fork illustration:

Note.—Slot-jaw and hole to be central and parallel on fork within 0.005 in.

In the table for the Turnbuckle Pin-Eye, the heading of the third column should be *E* instead of "Pitch Diameter."

GENERATOR MOUNTINGS

(*Proposed S.A.E. Standard, p.* 708)

FUEL-PUMP MOUNTINGS

(*Proposed S.A.E. Standard, p.* 708)

ENGINE-STARTER MOUNTINGS

(*Proposed S.A.E. Standard, p.* 708)

PROPELLER-HUB SHAFT-ENDS

(*Proposed S.A.E. Standard, p.* 707)

After the original report was printed the Aeronautic Division made a complete new report involving a change in the original No. 3 8-spline shaft-end to a short 16-spline shaft-end, and the inclusion of an additional small spline-shaft. The report, as submitted to and approved by the Standards Committee, involves the retention of the Nos. 1 and 2 taper shaft-ends as originally proposed, with the addition of tolerances, and three-spline shaft-ends with specified tolerances on the dimensions. Additional details included were the dimensions, with tolerances, of the propeller-hub itself. The standard thus provides a choice of two types of shaft-end.

The threads are shown only as general information in notes following the tables, this information not being a part of the standard at present because of the varying practices. It is anticipated, however, that standardization of the thread sizes will be accomplished by the Aeronautic Division prior to the next Standards Committee meeting.

The entire specification is as follows:

(*Sheets* 1 *and* 2)

Note.—(General Information only.) The thread in use at present on the No.-20 shaft-end is 2 1/4-12 American Standard NF, pitch diameter 2.070+0.000, —0.002.

The thread sizes in use for shaft No. 30 are 1 5/8-16 internal thread American Standard NF class 3 on the Pratt & Whitney Wasp engine; 2 1/8-12 external thread American Standard NF on the engines of the Wright Aeronautical Corporation; and 2 3/8-12 external thread American Standard NF, pitch diameter 2.320+0.000—0.002, on the Chieftain engines manufactured by the Curtiss Aeroplane & Motor Co.

The thread on the No.-40 shaft-end as now generally used is 2 7/8-12 American Standard NF, with a pitch diameter of 2.820+0.000—0.002.

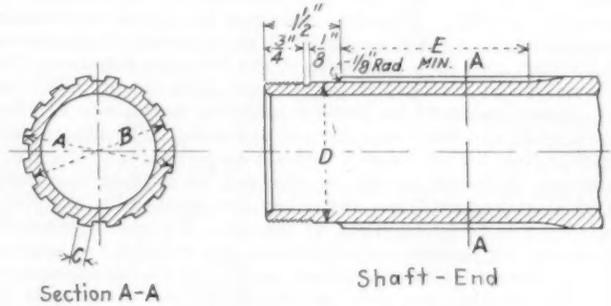
The threads on these shaft-ends will be taken under consideration immediately by the Aeronautic Division for standardization.

(*Sheet* 3)

PROPELLER-HUBS AND SHAFT-ENDS

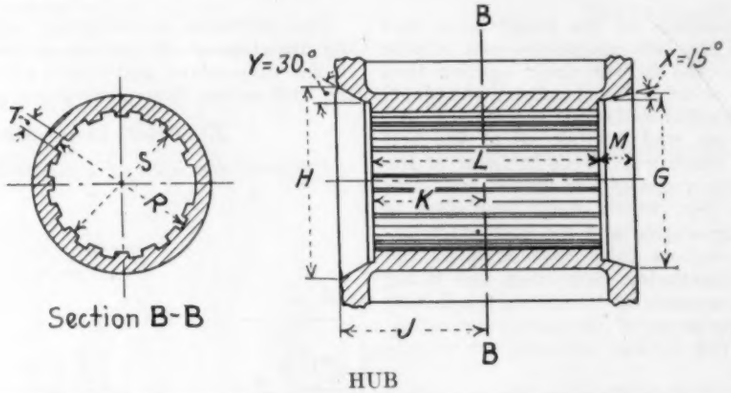
AERONAUTIC, SPLINED TYPE

(*Proposed S.A.E. Standard*)



SHAFT

Shaft No.	*A*	*B*	*C*	*D*	*E* Effective Length	Thread	No. of Splines
20	2.375+0.000 −0.002	2.156±0.001	0.231±0.0005	2.125+0.000 −0.002	4 1/16	See note on thread information below table	16
30	2.625±0.001	2.406+0.005 −0.002	0.257±0.0008	2.375+0.000 −0.002	4 1/16		16
40	3.125+0.000 −0.002	2.875±0.001	0.304±0.0008	2.875+0.000 −0.002	4 1/4		16

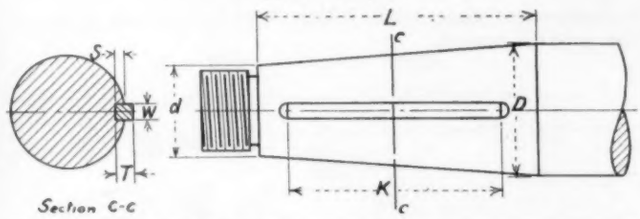


HUB

Hub No.	H Front End	G Rear End	J	K	L	M	R	S	T	Angle X For Rear Cone, Deg.	Angle Y For Front Cone, Deg.
20	3.125+0.005 −0.000	2.875+0.005 −0.000	2 25/32	2 3/16	4 3/8	5/8	2.381±0.002	2.162±0.002	0.233±0.0005	15	30
30	See	Note	2 25/32	2 3/16	4 3/8	5/8	2.633+0.005 −0.002	2.414+0.005 −0.002	0.259±0.001	15	30
40	3.875+0.005 −0.000	3.625+0.005 −0.000	2 5/8	2	4	5/8	3.131±0.002	2.881±0.002	0.306±0.0005	15	30

Note.—Corrected dimensions will be given in the supplement to the 1928 issue of the S.A.E. HANDBOOK, that will include this report.

TAPER TYPE



Shaft No.	L Length	Included Angle[1]	d Diameter at Small End	D Diameter at Large End	Key K Length	Key W Width	Key T Thickness	Key S
1	5 5/32	5°43'30" 1.2 in per ft.	1.535	2.05	3	0.375+0.0000 −0.0005	0.2775±0.0005	0.156±0.002
2	7	5°43'30" 1.2 in. per ft.	1.662	2.362	5 1/16	0.473±0.001	0.236+0.001 −0.002	0.148±0.005

[1] The taper should vary from absolute uniformity by being from 0.000 to 0.001 in. large at the large end.

Note.—(General Information only.) Threads generally used on the No.-1 taper shaft-end is 1½-18 (external) American Standard NF, or 15/16-24 (internal) American Standard NF.

The thread in general use on the No.-2 taper shaft-end is 1 9/16-12 (external) American Standard NF.

INSTRUMENT MOUNTINGS

(*Proposed S.A.E. Recommended Practice, p.* 709)

The heading in the third column of the table should be *D* instead of *C*.

ELECTRICAL EQUIPMENT DIVISION

CABLE TERMINALS

(*Proposed Revision of Present S.A.E. Standard, p.* 710)

[9] M.S.A.E.—Vice-president, chief engineer, Wisconsin Motor Mfg. Co., Milwaukee.

[10] M.S.A.E.—Detroit.

CABLE, CONDUIT AND TUBING CLIPS

(*Proposed Revision of Present S.A.E. Standard,* p. 711)

FLEXIBLE-CONDUIT FERRULES

(*Proposed S.A.E. Standard, p.* 711)

ENGINE DIVISION

DUPLEX-CARBURETER FLANGES

(*Proposed S.A.E. Recommended Practice, p.* 712)

AIR-CLEANER MOUNTINGS

(*Proposed S.A.E. Recommended Practice, p.* 712)

FANS, BELTS AND PULLEYS

(*Proposed Revision for S.A.E. Standard, p.* 713)

THE DISCUSSION

A. F. MILBRATH[9]:—At the meeting of the Standards Committee last January, the 38-deg.-angle pulley for V belts was recommended but the report was referred back to the Division. The matter was given considerable further study and investigation and it was finally the decision of the Division that the original report be again recommended to the Standards Committee.

G. WALKER GILMER[10]:—Although I was one of the objectors to this report at the last meeting of the Standards Committee, I think it should be approved now as presented. I have studied this matter and am satisfied that the work of the Division represents a lot of real effort and that it is the best we can do at this time.

VICE-CHAIRMAN STRICKLAND:—The old standard specified the 38-deg. pulley for driving fans only, or a 28-deg. pulley when other apparatus was driven by the same belt. I have not seen a report as to why the 28-deg. pulley is no longer necessary; which was the reason that I objected to the recommendation last January.

MR. MILBRATH:—The members of the Subdivision that prepared the report were fan-belt manufacturers, engine manufacturers and others, and it was their opinion that the 38-deg. pulley is more suitable for a general standard, for driving simply a fan or a fan and other accessories. All of the engine manufacturers, and I think all of the belt manufacturers we were in touch with, were in favor of the 38-deg. pulley. The average angle of 325 makes and sizes of belt now in use is 38¼ deg., which comes very close to what is recommended by the engine and the best manufacturers. The Subdivision realizes fully that some of the larger passenger-car manufacturing companies are using the 28-deg. pulley but, in a number of instances, the S.A.E. Standard is not followed by some of the larger manufacturers. Nevertheless, we felt it was advisable to recommend only one pulley-angle.

SPARK-PLUG TOLERANCES

(*Proposed Revision of Present S.A.E. Standard, p.* 714)

MOTORCYCLE SPARK-PLUGS

(*Proposed Cancellation of Present S.A.E. Recommended Practice,* p. 714)

IRON AND STEEL DIVISION

PHOSPHORUS AND SULPHUR CONTENT

(*Proposed Revision of Present S.A.E. Standard, p.* 715)

NICKEL STEELS

(*Proposed Revision of Present S.A.E. Standard, p.* 715)

LIGHTING DIVISION

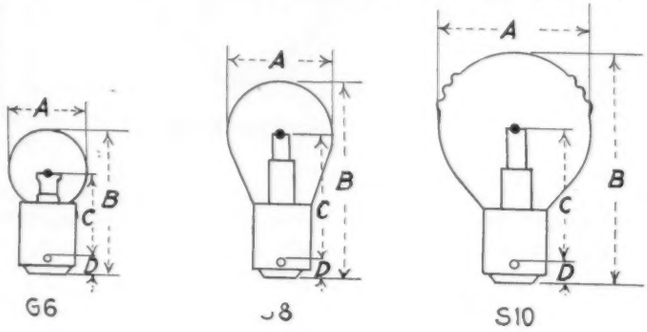
INCANDESCENT-LAMP BASES AND SOCKETS

(*Proposed Revision of Present S.A.E. Standard, p.* 715)

The corrected specifications as approved are shown in the drawings at the bottom of the page, the changes being in the dimensions and limits of the solder heights and in the dimensions dependent thereon.

ELECTRIC INCANDESCENT LAMPS

(*Proposed Revision of Present S.A.E. Standard, p.* 716)



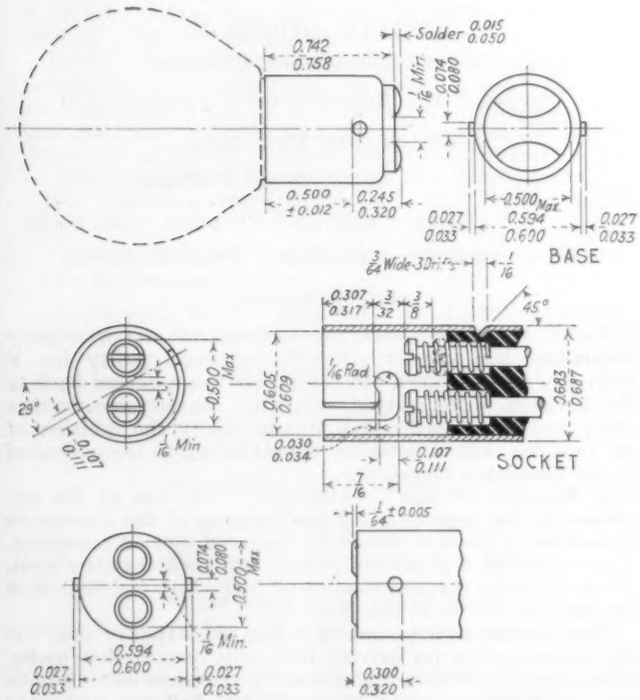
ELECTRIC INCANDESCENT LAMPS

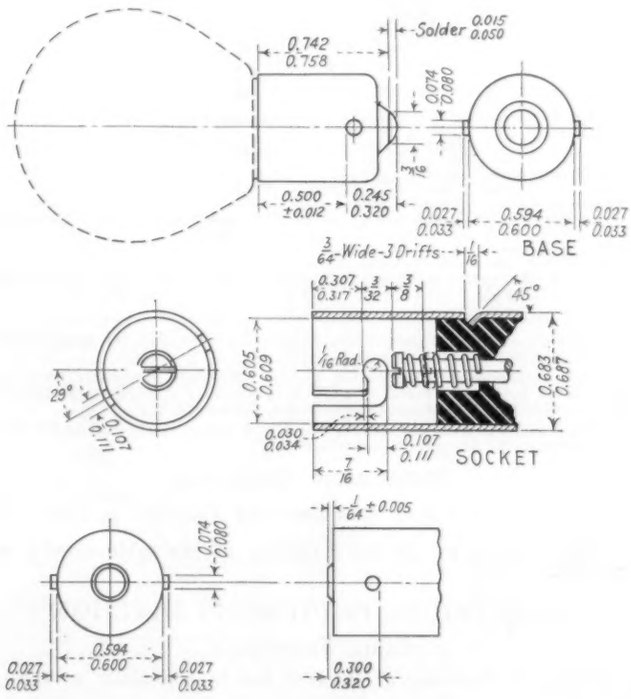
Dimension	G-6	G-8	S-8	S-10[a]
A	3/4	1	1	1–1/4
B	1–7/16	1–3/4	2	2–3/8
C[u]	3/4	7/8	1–1/8	1–1/4
D Max.	0.320	0.320	0.320	0.320

[a] The corrugations on electric incandescent lamps for headlight service shall be of sufficient depth to break up the filament image. The spacing between the filaments of the depressed-beam or two-filament type of incandescent lamp shall be 0.140 in. ± 0.016 in.

[u] Light-center length and axial alignment tolerances for headlight lamps are ± 3/64 in.

The following corrected tabulation indicates the corrections made in dimensions *B* and *D* and the revision of the 6-cp. 40-44 lamp and 6-volt 6-8 lamp to show the proper bulb-type and dimensions, which were erroneously given in the original report.





ELECTRIC INCANDESCENT LAMP DATA

General Information

Candle-Power	Voltage	Maximum Amperage[12]	Bayonet-Base Contact[13]	Bulb Type	Bulb Diameter, In.	Maximum Overall Length, In.	Light-Center Length, In.	Filament Form[14]
2	3–4	1.00	S or D	G-6	3/4	1 7/16	3/4	C-2
3	6–8	0.75	S or D	G-6	3/4	1 7/16	3/4	C-2
3	12–16	0.50	S or D	G-6	3/4	1 7/16	3/4	C-2
3	18–24	0.25	S or D	G-6	3/4	1 7/16	3/4	C-2
6	6–8	1.25	S or D	G-6	3/4	1 7/16	3/4	C-2
6	12–16	0.75	S or D	G-8	1	1 3/4	7/8	C-2
6	40–44	0.25	D	S-8	1	2	1 1/8	C-5
15	6–8	2.00	S or D	S-8	1	2	1 1/8	C-2
15	12–16	1.25	S or D	S-8	1	2	1 1/8	C-2
21	6–8	3.00	D	S-10	1 3/8	2 3/8	1 1/4	C-2
21		3.00					1 1/4	C-2
21	6–8	3.00	S or D	S-10	1 1/4	2 3/4	1 1/4	C-2
21	12–16	1.50	S or D	S-10	1 1/4	2 3/4	1 1/4	C-2
21	40–44	0.50	D	S-10	1 1/4	2 3/4	1 1/4	C-13
21	6–8	3.00	D	S-10	1 1/4	2 3/4	1 1/4	C-2
2		0.75		S-10	1 1/4	2 3/4		C-12
27	18–24	1.25	D	S-10	1 1/4	2 3/4	1 1/4	C-2
32	6–8	4.00	S or D	S-10	1 1/4	2 3/4	1 1/4	C-2
32	12–16	2.00	S or D	S-10	1 1/4	2 3/4	1 1/4	C-2

[12] Improvements in lamp design and manufacture from time to time make possible changes in ampere ratings. The figures given are therefore maximum and are for use in calculating wire sizes and battery capacities. For test purposes the exact amperage should be obtained from the lamp manufacturer.

[13] S—Single-contact. D—Double-contact.

[14] C indicates a coiled-wire filament.

Heavy-Duty Connectors

(*Proposed Extension of Present S.A.E. Standard, p.* 716)

The relative position of the pins in the plug and the slots in the sockets as shown in the June issue of THE JOURNAL is incorrect but will be rectified when the specifications are published.

PASSENGER-CAR DIVISION

Car-Frame Numbers

(*Proposed Cancellation of Present S.A.E. Standard, p.* 717)

Car-Performance Tests

(*Proposed Cancellation of Present S.A.E. Standard, p.* 717)

[15] M.S.A.E.—Manager, standards department, Society of Automotive Engineers, Inc., New York City.

Plate Glass

(*Proposed Revision of Present S.A.E. Recommended Practice, p.* 717)

Steering-Wheel Tests

(*Proposed S.A.E. Recommended Practice, p.* 717)

Body-Parts Nomenclature

(*Proposed S.A.E. Standard, p.* 718)

The list of parts names given on p. 718 of the June issue of THE JOURNAL should be disregarded and the part names as given on p. 594 of the May, 1928, issue substituted therefor.

PRODUCTION DIVISION

Tool-Holder Shanks and Tool-Post Openings

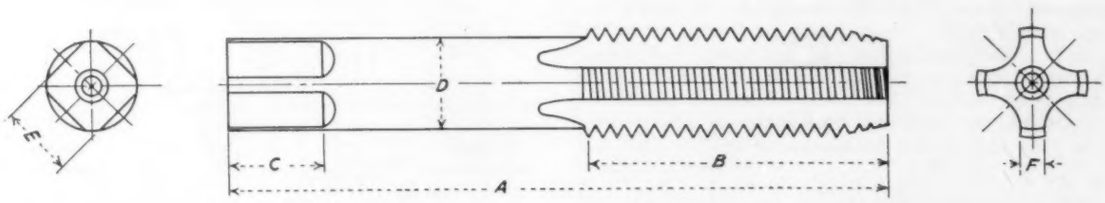
(*Proposed Approval for American Standard, p.* 719)

This report was submitted for approval by the Society as one of the sponsors for the Sectional Committee on Small Tools and Machine-Tool Elements, organized and working under the procedure of the American Engineering Standards Committee.

R. S. BURNETT[15]:—Since this report was printed in the June issue of THE JOURNAL, the Sectional Committee on Small Tools and Machine-Tool Elements, which prepared the report, has considered making some minor changes in it and the approval of the report at this time by the Society should cover these changes.

Changes in the Report

The following changes should be made in the table printed on p. 719 of the June issue of THE JOURNAL: The minimum height of lathe-post opening *D* for the No.-5 tool should be 3.16; for the No.-7 tool, 4.29, and the No.-9 tool, 5.80; the minimum width of lathe-post opening *W* should by 1.91 for the No.-7 tool and 2.27 for the No.-8 tool. The nominal size for the planer and shaper opening should be 3 x 1⅝ for the No.-6 tool. The minimum height of planer



SPARK-PLUG TAPS

Size	Pitch Diameter			Major Diameter			*A*	*B*	*C*	*D*	*E*	*F*
	Basic	Minimum	Maximum	Basic	Minimum	Maximum						
18 mm.[16]	.....	0.6709	0.6717	.....	0.7130	0.7145	4 1/32	1 13/16	5/8	0.542	0.407	0.178
7/8–18	0.8389	0.8399	0.8407	0.8750	0.8785	0.8805	4 11/16	2 11/32	3/4	0.697	0.523	0.212

[16] Pitch = 1½ mm.

General Specifications

Over-all length, A
+or—1/32 in.

Square length, C
+or—1/16 in.

Square size, E
+zero; —0.006 in.

Centers
Female

Chamfer
3 to 4 threads

Lead Error
+or—0.0005 in. per inch of thread

Thread length, B
+or—3/32 in.

Shank diameter, D
+zero; —0.002 in.

Land Width, F
Included angle, 28 deg.

Number of flutes
Four

Minor diameter
American Form or Sharper

Relief
Back taper 0.0005 to 0.001 in. per inch. Slight eccentric relief permissible

and shaper-post opening *E* should be 2.92 for the No.-6 tool, and the minimum width *W* should be 1.91 for the No.-7 tool and 2.57 for the No.-8 tool. The maximum lathe center-height *C* for the No.-5 tool should be 2.32.

Cut and Ground Taps

(Proposed Revision of Present S.A.E. Standard)

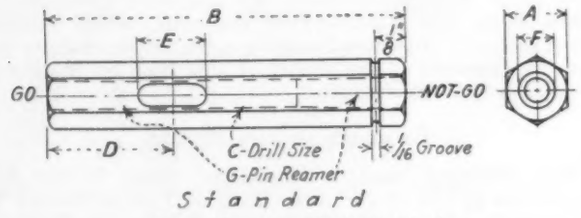
Mr. Burnett:—Since printing this report in the June issue of The Journal, we have received from Mr. Ovaitt, Chairman of the Tap and Gage Committee of the General Motors Corporation, a similar specification for Spark-Plug Taps which we would like to include in the revision of the present standard. The Production Division has cooperated with the General Motors Corporation Committee in the adoption of all the present tap specifications.

[The table mentioned is printed on p. 207.]

Cylindrical and Threaded Plug-Gages

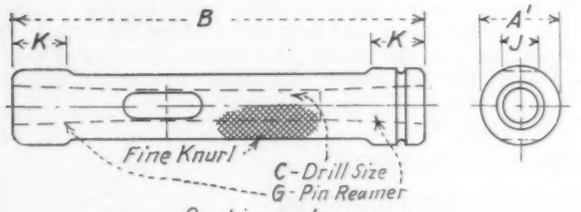
(Proposed S.A.E. Recommended Practice, p. 721)

The corrected specifications for the cylindrical and threaded plug-gages, as approved at the Standards Committee Meeting, follow. The detail dimensions and general specifications for the threads on the threaded plug-gages are those given in the table on p. 723 of the June issue of The Journal.



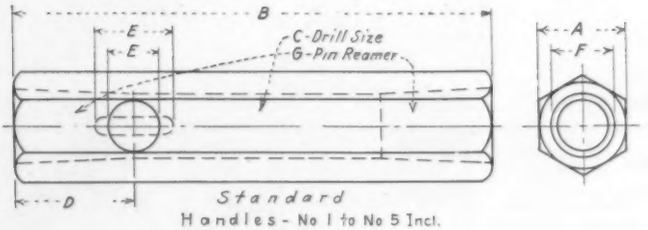
Standard

Handles - No. 000 to No. 0 Incl



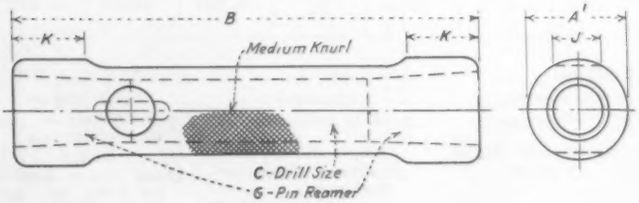
Optional

Handles - No. 000 to No. 0 Incl



Standard

Handles - No 1 to No 5 Incl.



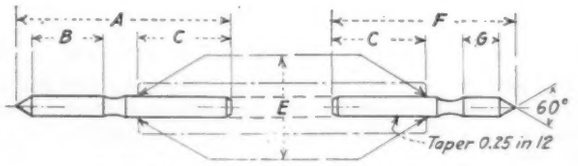
Optional

Handles - No 1 to No. 5 Incl

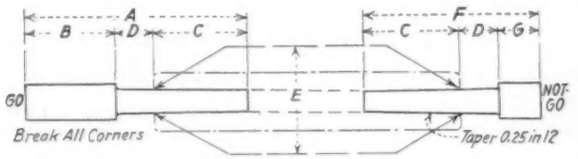
Handles

Handle Size	*A*	*B*	Drill *C*	*D*	*E*	*F*	*G*	*A'*	*J*	*K*
000	3/16	1½	No. 34 (0.111)	9/16	5/64x1¼	0.125 0.126	No. 000	¼	5/32	¼
00	¼	1¾	No. 29 (0.136)	5/8	3/32x5/16	0.155 0.156	No. 0	5/16	3/16	¼
0	5/16	2	No. 20 (0.161)	11/16	1/8x3/8	0.180 0.181	No. 2	3/8	3/16	¼
1	3/8	2¾	7/32	25/32	1/8x1½	0.239 0.240	No. 4	7/16	7/32	½
2	½	3	L (0.290)	25/32	15/64	0.309 0.310	No. 6	5/8	3/8	½
3	11/16	3¼	25/64	27/32	11/32	0.409 0.410	No. 7	13/16	7/16	½
4	7/8	3⅝	37/64	63/64	3/8	0.609 0.610	No. 10	1 1/16	7/16	9/16
5	1⅛	4	25/32	1⅛	7/16	0.809 0.810	No. 11	1 5/16	½	5/8
5 Opt. Range	1⅛	4	25/32	1⅛	7/16	0.809 0.810	No. 11	1 5/16	½	5/8

The groove in the Not-Go end of the handle is to distinguish it from the Go end.



Cylindrical Plugs - Above 0.059 to 0.150 Incl.

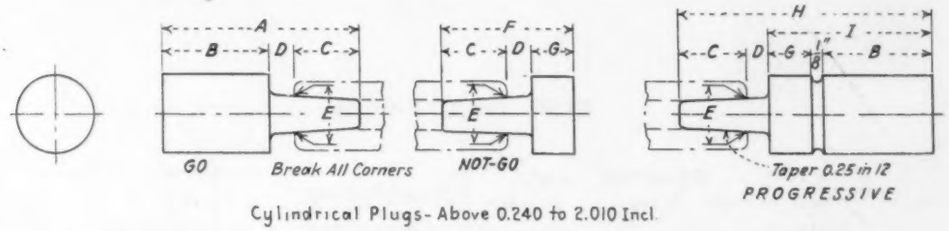


Cylindrical Plugs - Above 0.150 to 0.240 Incl.

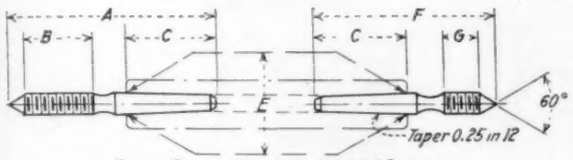
Cylindrical Plugs

Range		Handle Size	Go		All			Not Go		Progressive	
Above	Including		*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
0.059	0.105	000	1 5/32	3/8	½		0.125 0.126	3 1/32	3/16		
0.105	0.150	00	1 11/32	7/16	9/16		0.155 0.156	1⅛	7/32		
0.150	0.240	0	1 15/32	1 9/32	5/8	¼	0.180 0.181	1 5/32	9/32		
0.240	0.365	1	1¾	¾	¾	¼	0.239 0.240	1 5/16	5/16	2 3/16	1 3/16
0.365	0.510	2	2	1	¾	¼	0.309 0.310	1⅝	⅜	2½	1½
0.510	0.825	3	2¼	1¼	¾	¼	0.408 0.410	1½	½	2⅞	1⅞
0.825	1.135	4	2 9/16	1⅜	⅞	5/16	0.608 0.610	1 13/16	⅝	3 5/16	2⅛
1.135	1.510	5	2⅞	1½	1	⅜	0.808 0.810	2⅛	¾	3¾	2⅝
1.510 Opt.	2.010 Range	5	2⅞	1½	1	⅜	0.808 0.810	2⅛	¾	3¾	2⅝

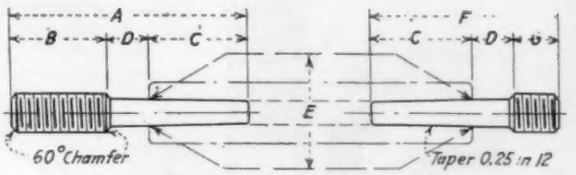
The optional range applies only to the cylindrical plug-gages.



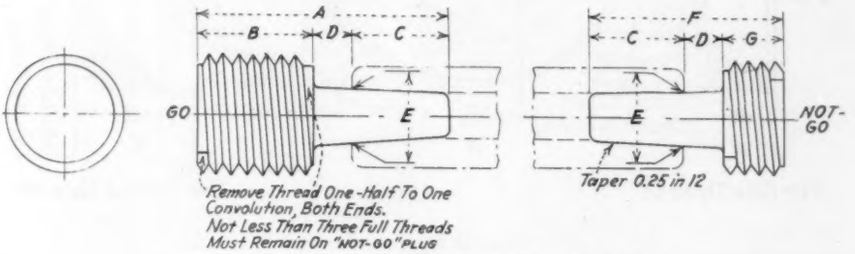
Cylindrical Plugs - Above 0.240 to 2.010 Incl.



Thread Plugs - Threads No 0 to No. 6 Incl



Thread Plugs - Threads No. 8 to No. 12 Incl



Thread Plugs - Threads ¼ to 1½ Incl.

Thread Plugs

Thread Sizes Inclusive	Handle Size	Go		Both			Not Go	
		A	*B*	*C*	*D*	*E*	*F*	*G*
Nos. 0 to 3	000	1 1/32	1/4	1/8		0.125 0.120	31/32	3/16
Nos. 4 to 6	00	17/32	5/16	9/16		0.155 0.156	1 1/8	7/32
Nos. 8 to 12	0	19/32	13/32	5/8	1/4	0.180 0.181	1 5/32	9/32
1/4 to 5/16	1	1 1/2	1/2	3/4	1/4	0.239 0.240	1 5/16	5/16
3/8 to 1/2	2	1 3/4	3/4	3/4	1/4	0.309 0.310	1 3/8	3/8
9/16 to 3/4	3	1 7/8	7/8	3/4	1/4	0.408 0.410	1 1/2	1/2
7/8 to 1 1/8	4	2 3/16	1	7/8	5/16	0.608 0.610	1 13/16	5/8
1 1/4 – 7	5	2 5/8	1 1/4	1	3/8	0.808 0.810	2 1/8	3/4
1 1/2 – 5	5	2 7/8	1 1/2	1	3/8	0.808 0.810	2 1/8	3/4
1 1/4 – 12 1 1/2 – 12	5 5	2 3/8 2 3/8	1 1	1 1	3/8 3/8	0.808 0.810	2 1/4 2 3/8	3/4 3/4

The shell type of design is recommended for thread plug-gages in all sizes above 1½ in. diameter.

RING THREAD-GAGES

(*Proposed S.A.E. Recommended Practice*, p. 721)

The corrected specification for the ring thread-gages, as approved at the Standards Committee Meeting, is given in the tables on pp. 210 and 211.

THE DISCUSSION

MR. BURNETT:—The reports on Cylindrical Plug and Thread-Gages and on Ring Thread-Gages originated in the committee known as the American Gage-Design Committee. The reports as printed in the June issue of THE JOURNAL were approved by the Production Division, but the American Gage-Design Committee held a meeting in Rochester last week at which I understand certain revisions were made in the table. Therefore, in presenting the reports for approval today, we should like to include the revisions that were made at Rochester.

EARLE BUCKINGHAM[17]:—At the time these standards were being formulated it was found that a rather complex patent situation existed with regard to the locking construction of a considerable number of the gages but all the gage manufacturers agreed to waive their patent rights and let the Committee adopt the one considered best. The company which held patents on the construction selected by the Committee agreed to grant free licenses back and forth so there would be no patent litigation of any sort. I think that was a very broadminded act on the part of the gage manufacturers.

[17] M.S.A.E.—Associate professor of engineering standards and measurement, Massachusetts Institute of Technology, Cambridge, Mass.

TIRE AND RIM DIVISION

BALLOON-TIRE SIZES

(*Proposed Revision for Present S.A.E. Standard*, p. 725)

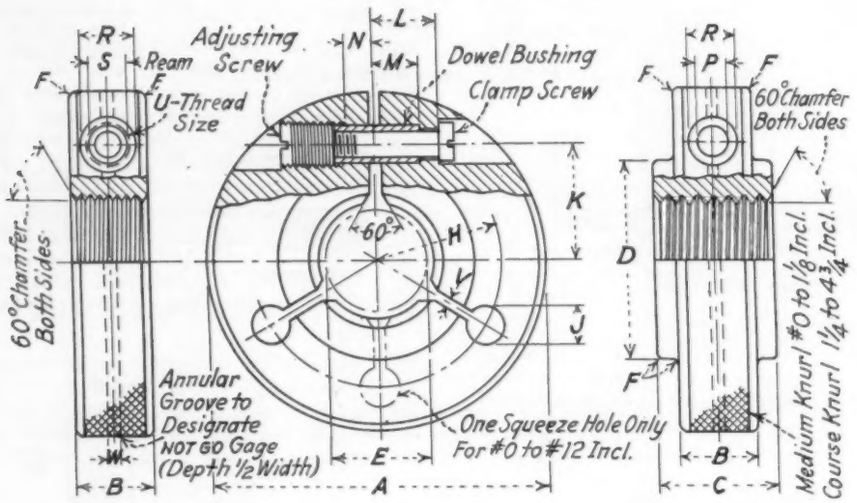
This report is proposed for adoption as S.A.E. Standard to replace the present S.A.E. Recommended Practice given on p. 293 of the 1928 edition of the S.A.E. HANDBOOK.

THE DISCUSSION

MR. STRICKLAND:—In conversation with Mr. Crane before the meeting regarding the balloon-tire standardization, I understood there is nothing to be done by the Standards Committee today, as he thought it would be best to leave the report *in statu quo* for the time being.

MR. HERRMANN:—We have worked so long on this report that we certainly should take very definite action today. I move that we act on this report in the usual way so that the industry will know where it stands with respect to this tire standard. It has been passed on by the Tire and Rim

RING THREAD-GAGE



For Fine Threads For Coarse Threads

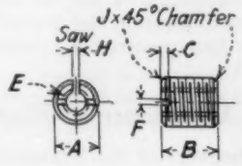
General Dimensions

Nominal Thread Size, Incl.	*A*	*B*	*C*	*D*	*E*	*F*	*H*	*J*	*K*	*L*	*M*	*N*	Drill *P*	Drill *R*	Ream *S*	*U* Size	*U* P.D.	*V*	*W*
Nos. 0 to 6	1	13/64	....	....	....	1/32	5/16	5/32	5/16	7/32	5/32	1/16	No. 41 (0.0960)	11/64 (0.1719)	0.1370 0.1373	No. 8-36	0.1460 0.1478	0.010 Approx.	1/32
Nos. 8 to 12	1	1/4	....	....	....	1/32	5/16	5/32	5/16	7/32	5/32	1/16	No. 41 (0.0960)	11/64 (0.1719)	0.1370 0.1373	No. 8-36	0.1460 0.1478	1/64	1/32
1/4-5/16	1 3/8	11/32	....	....	5/32	1/32	7/16	3/16	3/8	11/32	1/4	1/8	No. 31 (0.1200)	7/32 (0.2187)	0.1810 0.1813	No. 12-28	0.1928 0.1950	1/32	1/16
3/8-1/2	1 3/4	7/16	....	....	3/16	3/64	19/32	1/4	15/32	1/2	3/8	3/16	No. 25 (0.1495)	17/64 (0.2656)	0.2150 0.2153	1/4-28	0.2268 0.2290	1/32	3/32
9/16-3/4	2 3/16	9/16	3/4	1 1/16	11/32	1/16	3/4	5/16	11/16	17/32	13/32	7/32	No. 7 (0.2010)	21/64 (0.3281)	0.2720 0.2723	5/16-24	0.2854 0.2878	1/16	3/32
7/8-1 1/8	2 5/8	11/16	15/16	1 1/2	9/16	1/16	31/32	5/16	7/8	17/32	13/32	9/32	No. 1 (0.2280)	25/64 (0.3906)	0.3340 0.3344	3/8-24	0.3479 0.3503	1/16	3/32
1 1/4-1 1/2	3 1/4	3/4	1 1/8	1 7/8	27/32	1/16	1 3/16	3/8	1 1/8	5/8	7/16	5/16	17/64 (0.2656)	29/64 (0.4531)	0.3890 0.3894	7/16-20	0.4050 0.4076	1/16	3/32
1 5/8-2	3 3/4	13/16	1 1/4	2 3/8	1 3/16	3/32	1 7/16	3/8	1 3/8	5/8	7/16	5/16	17/64 (0.2656)	29/64 (0.4531)	0.3890 0.3894	7/16-20	0.4050 0.4076	1/16	1/8
2 1/8-2 1/2	4 1/2	7/8	1 5/16	2 7/8	1 19/32	3/32	1 3/4	7/16	1 11/16	13/16	9/16	7/16	21/64 (0.3281)	33/64 (0.5156)	0.4510 0.4515	1/2-20	0.4675 0.4701	3/32	1/8
2 5/8-3	5	7/8	1 3/8	3 3/8	2	3/32	2	7/16	1 15/16	13/16	9/16	7/16	21/64 (0.3281)	33/64 (.05156)	0.4510 0.4515	1/2-20	0.4675 0.4701	3/32	1/8
3 1/8-3 1/2	5 1/2	15/16	1 7/16	3 7/8	2 7/16	3/32	2 7/32	7/16	2 3/16	13/16	9/16	7/16	21/64 (0.3281)	33/64 (0.5156)	0.4510 0.4515	1/2-20	0.4675 0.4701	3/32	1/8
3 5/8-4	6 3/8	15/16	1 1/2	4 5/8	2 15/16	3/32	2 5/8	1/2	2 9/16	1	3/4	5/8	13/32 (0.4062)	41/64 (0.6406)	0.5710 0.5715	5/8-18	0.5889 0.5919	3/32	1/8
4 1/8-4 3/4	7 1/4	1	1 1/2	5 3/8	3 3/8	3/32	3 1/32	1/2	3	1	3/4	5/8	13/32 (0.4062)	41/64 (0.6406)	0.5710 0.5715	5/8-18	0.5889 0.5919	3/32	1/8

RING THREAD-GAGE

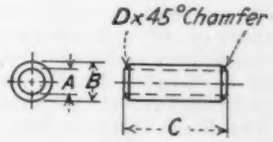
Adjusting Screw

A		Minor Diam.	B	C	E			F	H	J
Size	P.D.				Size	P.D.	Drill			
8–36	0.1442 0.1460	0.1315 0.1333	3/16	3/64	No. 2-64	0.0759 0.0773	No. 50 (0.0700)	1/32	1/64	0.020
12–28	0.1906 0.1928	0.1744 0.1766	1/4	3/64	No. 4-48	0.0985 0.1001	No. 42 (0.0930)	1/32	1/64	0.020
1/4–28	0.2246 0.2268	0.2084 0.2106	5/16	1/16	No. 6-40	0.1218 0.1235	No. 32 (0.1160)	3/64	1/32	0.020
5/16–24	0.2830 0.2854	0.2641 0.2665	5/16	1/16	No.10-32	0.1697 0.1716	No. 20 (0.1610)	3/64	1/32	1/32
3/8–24	0.3455 0.3479	0.3266 0.3290	3/8	5/64	No.12-28	0.1928 0.1950	No. 14 (0.1820)	1/16	3/64	1/32
7/16–20	0.4024 0.4050	0.3797 0.3823	7/16	5/64	1/4–28	0.2268 0.2290	No. 3 (0.2130)	1/16	3/64	1/32
1/2–20	0.4649 0.4675	0.4422 0.4448	1/2	3/32	5/16–24	0.2854 0.2878	I (0.2720)	5/64	1/16	3/64
5/8–18	0.5859 0.5889	0.5607 0.5637	9/16	3/32	3/8–24	0.3479 0.3503	Q (0.3320)	5/64	1/16	3/64

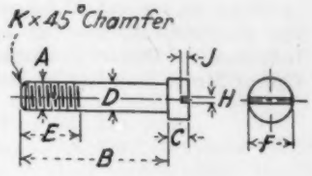


Adjusting Screw

Dowel Bushing				Clamp Screw									
Drill A	B	C	D	A		B	C	D	E	F	H	J	K
				Size	P.D.								
No. 43 (0.0890)	0.1368 0.1370	1/4	0.010	No. 2-64	0.0745 0.0759	29/64	5/64	0.0840 0.0860	3/16	5/32	1/32	3/64	0.010
No. 32 (0.1160)	0.1808 0.1810	7/16	0.020	No. 4-48	0.0969 0.0985	23/32	3/32	0.1100 0.1120	5/16	3/16	1/32	3/64	0.020
No. 27 (0.1440)	0.2148 0.2150	5/8	0.020	No. 6-40	0.1201 0.1218	1	1/8	0.1360 0.1380	7/16	7/32	3/64	1/16	0.020
No. 10 (0.1930)	0.2718 0.2720	11/16	1/32	No.10-32	0.1678 0.1697	1 1/16	1/8	0.1880 0.1900	7/16	9/32	3/64	1/16	1/32
No. 2 (0.2210)	0.3337 0.3340	3/4	1/32	No.12-28	0.1906 0.1928	1 3/16	5/32	0.2140 0.2160	1/2	11/32	1/16	1/16	1/32
F (0.2570)	0.3887 0.3890	13/16	1/32	1/4–28	0.2246 0.2268	1 23/64	3/16	0.2480 0.2500	9/16	13/32	1/16	5/64	1/32
P (0.3230)	0.4507 0.4510	1 1/16	3/64	5/16–24	0.2830 0.2854	1 23/32	1/4	0.3105 0.3125	5/8	15/32	5/64	3/32	3/64
25/64 (0.390)	0.5707 0.5710	1 1/2	3/64	3/8–24	0.3455 0.3479	2 3/16	5/16	0.3730 0.3750	3/4	19/32	5/64	3/32	3/64



Dowel Bushing



Clamp Screw

Note: Thin gage-blanks are to be used for National fine-thread ring-gages and Not-Go gages and all National coarse-thread ring-gages up to and including 1/2-in. size. Thick blanks are to be used for all National coarse-thread ring-gages above 1/2-in. size.

It is recommended that standard ring thread-gage blanks be used for special pitches as follows:

No. 0 to 1/2 in., inclusive, thin blanks for all pitches.

9/16 to 1 1/8-in., inclusive, thin blanks for 12 threads per inch and finer, and thick blanks for pitches coarser than 12 threads per inch.

Above 1 1/8-in., thin blanks, for 10 threads per inch and finer, and thick blanks for pitches coarser than 10 threads per inch.

Association, the Rubber Association of America, the National Automobile Chamber of Commerce and the Society in joint committee substantially as it is presented here. Motor-car companies are planning to go ahead with their selection of tire sizes, and to hold this matter open for another six months until we can get together again will be decidedly injurious to the progress of this important work. Although there have been some modifications of what was first agreed to, I really feel this is a great accomplishment and should be passed on today. Any future revisions or suggestions can be considered at our meeting next January or at our next Summer Meeting. The report is decidedly a step ahead, and for us to hold it up now will perhaps tend toward leaving the industry to get away from something that has required a tremendous amount of work to accomplish.

Attendance at Standard Committee Meeting

Members of the Standards Committee and other members of the Society and its guests in attendance at the Standards Committee Meeting were as follows:

Standards Committee Members

Azel Ames
B. B. Bachman
C. C. Bohner
H. S. Broadbent
H. E. Brunner
Earle Buckingham
R. S. Burnett
S. R. Castor
L. A. Chaminade
C. F. Clarkson
J. C. Geniesse
H. W. Graham
J. E. Hale
J. D. Harris
K. L. Herrmann
M. C. Horine
Herbert Jandus
W. C. Keys
C. M. Larson
B. J. Lemon
L. E. Lighton
A. F. Milbrath
S. W. Mills
F. H. Prescott
H. J. Saladin
A. J. Scaife
W. R. Strickland
J. G. Swain
A. J. Underwood
George Walther
Hon. E. P. Warner
F. G. Whittington

Society Members and Guests

W. R. Anderson
C. E. Banta
C. Bockins
E. Botts
R. A. Brannigan
F. G. Bremer
L. D. Byce
J. T. Caldwell
C. S. Clark
A. Ferrier
Walker Gilmer
P. M. Heldt
F. N. Horton
H. F. Huf
J. H. Hunt
W. M. Johnson
C. L. Knopf
W. L. McGrath
R. E. Plimpton
E. Reid
H. F. Schippel
A. E. Snyder
R. E. Wilkin

The Fifth World Motor-Transport Congress

PLANS are well advanced for the Fifth World Motor-Transport Congress to be held in Rome, Italy, in September, and an invitation has been received by the Society to be represented and for the presentation of one or more papers by its representatives. The first three of these Congresses were held in America, and the fourth Congress, held in London last November, was attended by several representatives of the Society.

The Rome Congress this year is organized jointly by the Italian Automobile Manufacturers Union and the Royal Automobile Club of Italy, under the auspices of the Permanent International Bureau of Automobile Builders, in Paris. It has the cooperation of the Italian Government, and assurances have been received that the State Departments of various countries will be represented. Five days, Sept. 25 to 29 inclusive, have been designated for the Congress, and the preliminary program shows three sessions to be held daily after the first day. There are to be official reports by delegates from Great Britain, Germany, Italy, France, and the United States; luncheons by the Executive Committee of the Congress, the Automobile Club of Rome, the Royal Automobile Club of Italy, and the Italian Government; various addresses; and papers on The Influence of Motor Transport on National Progress, The Use of Motor-Vehicles by National and Local Governments, Motor Fuel and Fuel Economy, Road Improvement and Its Finance, Cooperation Between Rail and Road Transport, and Means of Stimulating the Sales of Motor-Vehicles through Improved Organization.

The object of the Congress is to discuss means to stimulate action by governments and other bodies along lines consistent with the development of road motor-transport throughout the world. Italian, French and English are designated the official languages.

Following the week of the Congress, 3 days—Oct. 1, 2 and 3—have been set aside for official visits to the Italian factories of the Isotta Fraschini, Fiat and Pirelli companies, the Milan Autodrome, the Autostrada Milan-Como, and trips on Lake Como to Bellagio and by coaches to Briga.

Dates fixed for the Congress are convenient for American delegates who may desire to attend it and afterward to visit the Automobile Salon in Paris and the Olympia Show in London. As usual, the National Automobile Chamber of Commerce will be represented officially.

Any member of the Society who desires to attend the Congress is requested to communicate promptly with the headquarters of the Society in New York City for full information, so that proper arrangements can be made through the chairman of the Executive Committee of the Congress, Count Romeo Gallenga Stuart.

Aluminum Production Expanding

THE expansion program of the aluminum industry is so extensive that a period of unusually severe competition seems to be ahead. The world production in 1927 is reported as about 450,000,000 lb. of primary aluminum, of which the United States contributed about 160,000,000 lb.

Important improvements in production methods and refining are in course of development. Commercial aluminum of a purity of 99.99 per cent is apparently in sight, and clay as a source of aluminum is beginning to be utilized in place of bauxite. Since bauxite deposits generally are now rather closely held, methods permitting the economical substitution of clay should favor competitive developments.

A favorable factor of importance in the aluminum situation is found in the increasing diversity of uses for the metal and its alloys. Wide application of both is being made in automobiles and aircraft, household utensils, and in steel works and foundries, while a new and broad field is opening up in the construction of railway and electric cars. The use of aluminum paints is extending rapidly, and aluminum is beginning to displace tin for collapsible tubes and to serve as a substitute for tin plate in milk cans. For certain types of chemical equipment the metal is proving almost indispensable.—Industrial Bulletin of Arthur D. Little.

Standardization Activities

Survey of S.A.E. Standards

Replies Form the Basis of Action by Standards Committee Divisions

ACTIVITY in the matter of surveys and questionnaires throughout the automotive industry has been increased recently by the Standards Department, in an endeavor both to determine the extent of use of present specifications and, somewhat more frequently, to obtain data on various subjects for the use of committees studying and formulating specifications for such subjects.

The percentage of replies is still unsatisfactory, although it is realized that in many instances the letters did not reach those persons most vitally concerned with the subject matter. In most cases, however, answers and information can be obtained from the majority of the active organizations whose interest in the Standardization Activities of the Society is indicative of their general progressiveness along all lines.

Front-Axle Hubs

A summary of replies on the use of the S.A.E. Specifications on Front-Axle Hubs, pp. 289-301, in the 1928 edition of the S.A.E. HANDBOOK, indicates that of 18 passenger-car companies only one uses these specifications. Twenty-six truck companies replied, showing that 2 use the specifications, 14 do not use them, and 10 leave the matter of axle and hub dimensions to the axle manufacturers.

The axle and wheel manufacturers, judging from the comments submitted, appear to follow various designs as required by other features of the chassis for which the axle and wheels are made. The type of bearings used also affects the design to a large extent. It is therefore evident that the S.A.E. Specifications are little used.

This matter has been submitted to the Axle and Wheels Division of the Standards Committee through a letter-ballot to determine whether the S.A.E. Specifications for Front-Axle Hubs should be revised or cancelled. Although a number of the replies in the survey indicate that many engineers feel that this is not a suitable subject for standardization, the letter-ballot of the Division will determine what action should be taken. If the consensus of opinion of the Division members is for revision, the chairman will appoint a subdivision to formulate such a revision. Otherwise this item will be submitted to the Standards Committee for cancellation.

Starting-Motor Cable

A survey of the use of the S.A.E. Standard on Starting-Motor Cable, pp. 126-131, of the 1928 edition of the S.A.E. HANDBOOK, indicates a widespread adoption of these specifications among the major passenger-car and truck manufacturers. Replies were received from 44 companies, of which 27 use the specifications entirely and 5 use them as a basis for purchasing. Twelve of the companies replying do not use this standard at all.

The summary of replies is being submitted to the Electrical Equipment Division and to the Subdivision on Insulated Cable, which is at present engaged in determining suitable physical-property specifications, involving corona, as it has been found that the present material specifications exclude some of the best-known and most widely used cable manufactured. It is anticipated that, should such specifications be developed, the best part of the present standard can be incorporated to produce a more thorough and complete standard for this item.

Charging Plugs

Information received from one of the largest manufacturers of charging plugs and receptacles indicates that the present S.A.E. Standard for these items for electric vehicles, p. 155 in the 1928 edition of the S.A.E. HANDBOOK, is in general use among manufacturers of this type of vehicle. More than 90 per cent of electric vehicles are equipped with this type of plug, which is also being used to a large extent on electric baggage-trucks. Aside from the vehicular use of S.A.E. Standard Plugs and Receptacles, the specification has been adopted to a great extent by the United States Government, for use particularly on docks for the transmitting of power to ships of the Navy when tied up.

Although the present specification calls for plugs of two capacities, namely, 50 and 150 amp., the former 50-amp. plug is now, at the request of the National Board of Underwriters, rated by the manufacturers as a 100-amp. plug. The Electric Vehicle Division will take under consideration the revising of the specifications relative to the change of rating of the 50-amp. plug.

This standard was adopted by the Society in 1916 and is a good example of the unifying of practice through standards for both the manufacturer and the user.

Heat-Treatment Definitions

THE Joint Committee of the American Society for Testing Materials, the American Society of Steel Treaters and the S.A.E. on Heat-Treatment Definitions recently recommended the following additional definitions under the present definition of annealing on p. 355 in the HANDBOOK.

Full Annealing.—Heating iron-base alloys above the critical temperature range, holding above that range for a proper period of time, followed by slow cooling through the range.

Note:—The annealing temperature is generally about 100 deg. fahr. above the upper limit of the critical temperature range, and the time of holding is usually not less than 1 hr. for each inch of section of the heaviest objects being treated. The objects being treated are ordinarily allowed to cool slowly in the furnace. They may, however, be removed from the furnace, and cooled in some medium which will prolong the time of cooling as compared with unrestricted cooling in the air.

Process Annealing.—Heating iron-base alloys to a temperature below or close to the lower limit of the critical range, followed by cooling as desired.

Note:—This heat-treatment is commonly applied in the sheet and wire industries, and the temperatures generally used are from 1020 to 1200 deg. fahr. (549 to 648 deg. cent.)

Patenting.—Heating iron-base alloys above the critical temperature range, followed by cooling to below that range in molten lead maintained at a temperature of about 700 deg. fahr. (367 deg. cent.)

Note:—This treatment is usually applied in the wire industry either as a finishing treatment or especially in the case of eutectoid steel as a treatment previous to further wire-drawing. Its purpose is to produce a sorbitic structure.

These additions have been submitted to the Iron and Steel Division of the Society and, if approved, will be submitted to the Standards Committee in January.

Operation and Maintenance

Questionnaires Submitted

Truck and Motorcoach Data Desired on Man-Power per Vehicle

THE subject of Man-Power Required per Vehicle Operated and Seasonal Fluctuations in Man-Power Requirements was chosen by the Operation and Maintenance Committee as being important to the operators, especially in cases where the fleet operation is a major activity and where the operators do their own maintenance work. Therefore, the accumulating of data was assigned to a Subcommittee, known as Subcommittee No. 4, under the chairmanship of F. C. Horner, who was assisted by Donald Blanchard in getting the work started.

As a result of preliminary study, the accompanying questionnaires have been prepared and sent to about 200 motor-truck fleet-operators and to about 50 of the major motorcoach fleet-operators. They are published herewith to give all members of the Society who are interested an opportunity to send in the information desired in the event that they have not directly received copies of the questionnaires.

Replies should be sent to the Standards Department of the Society in New York City, to be analyzed by the Subcommittee and used in preparing a report for presentation at one of the sessions of the Annual National Transportation Meeting of the Society, which is to be held at the Robert Treat Hotel in Newark, N. J., Oct. 17 to 19, 1928.

If any operating member wishes to fill in the regular questionnaire blank and will so notify the Standards Department, copies of these questionnaires will be sent him. Further, any operator who is not a member of the Society can obtain a copy of the report after it has been submitted by requesting it of the Standards Department.

All who respond to the questionnaire with the information asked for should do so as soon as possible, so that the Subcommittee's report can be drafted from them and submitted to the members of the Operation and Maintenance Committee for comment. If revision of the Subcommittee report then seems advisable, there will be time enough for such revision before the presentation of the report at the Transportation Meeting.

Motor-Truck and Motorcoach Questionnaires

The questionnaires are combined on p. 215 in the following manner. For use as a Motor-Truck Questionnaire, strike out question 1-B, retaining question 1-A. For use as a Motorcoach Questionnaire, strike out question 1-A and retain question 1-B.

Work of the Subcommittees

PRESENT activities of the subcommittees of the Operation and Maintenance Committee are centered on the accumulating of data for the preparation of preliminary reports to be circulated among the members of the Committee for criticism, and on the preparation of final reports to be presented at the National Transportation Meeting in Newark, N. J., Oct. 17 to 19.

J. F. Winchester's preliminary work on developing standardized Mechanical Information-Sheets was published in the July issue of THE JOURNAL, p. 120. These sheets will make it possible for fleet operators to tabulate accurate records of mechanical parts and other information received from vehicle manufacturers for service and parts-replacement purposes.

E. C. Wood's program includes a broad study of the value of accessories with relation to maintenance requirements, and questionnaires on man-power requirements have been sent out by F. C. Horner's subcommittee. It is expected that the resulting information will be the basis for valuable reports on these three important subjects.

The subcommittee of which T. L. Preble is chairman has been collecting data on the selecting and training of mechanics and their payment, together with information relating to time-study; and the same can be said of the subcommittee headed by Ethelbert Favary, on the subjects of drivers, their selection, training and payment, as well as safety measures affecting operation.

Administrative systems and methods, budgeting methods and practices, are subjects being investigated by the subcommittees under the leadership of L. V. Newton and W. F. Banks, respectively. In connection with motor-vehicle cost-accounting, Mr. Newton says: "I feel that the Society can establish the fundamentals of a good cost-determination plan, and get variable charges defined and treated alike so that comparisons can be made between them on a ton-mile basis." The purpose of this study is more specifically to provide a comparable system of cost-determination and classification by fleet-operating and maintenance engineers, but not to develop an accounting system.

Data Desired on Accessories

Air-Cleaner, Shock-Absorber and Oil-Filter Effect on Maintenance

IN working up his assigned subject, The Effect on Vehicle Maintenance of the Use of Such Accessories and Parts as Air-Cleaners, Oil-Filters, and Shock-Absorbers, E. C. Wood, chairman of Subcommittee No. 2 of the Operation and Maintenance Committee, has sent questionnaires to the members in the operating group on the Pacific Coast and will welcome detailed information from those located elsewhere. The information desired has to do mainly with the effect of these devices on maintenance costs, and it should be addressed to the Standards Department of the Society in New York City for transmittal to Mr. Wood.

The questionnaires sent out by Mr. Wood are printed herewith.

Questionnaire on Air-Cleaners

What type and make of air-cleaner do you consider the most efficient?

What results have you obtained with regard to air-velocity changes and fuel consumption?

At what period of time or mileage do you recondition the air-cleaners?

What percentage of engine maintenance can be credited to the air-cleaner?

What percentage of solid material is held in suspension under average conditions in your locality?

What percentage of the atmosphere is cleaned by the filter or cleaner?

What failures have you had with air-cleaners?

MOTOR-TRUCK AND MOTORCOACH QUESTIONNAIRES

1-A. How many trucks do you operate?..... (Please classify as to capacity and body type).

Body Types	Motor-Truck Capacities, Tons					
	1 and Less	1½ to 2	Over 2 to 3½	Over 3½	Tractors	Trailers
Panel						
Screen Side						
Platform						
Dump						
Tank						
Other Types						

1-B. How many motorcoaches (buses) do you operate?..... (Please classify as follows):

Body Types	Number of Passenger Seats per Vehicle	Number of Vehicles
(*a*) City (Single-Deck)		
(*b*) Suburban (Single-Deck)		
(*c*) Parlor Car		
(*d*) Raised-Deck Parlor-Car		
(*e*) Sedan		
(*f*) Double-Deck		

Definitions—

(*a*) City (Single-Deck) type is for mass transportation to carry both seated and standing passengers.

(*b*) Suburban (Single-Deck) type has a longitudinal aisle and cross-seats and provides for a limited number of standing passengers.

(*c*) Parlor-Car type has a longitudinal center-aisle and carries seated passengers only.

(*d*) Raised-Deck Parlor-Car type has a part of the passengers' compartment-deck constructed on the chassis frame, and the other part constructed over a compartment or other space not used for passengers.

(*e*) Sedan type has full-width transverse-seats and more than two entrance doors, and is for carrying seated passengers only.

(*f*) Double-Deck type has two-passenger-decks, one directly over the other. This type does not include the raised-deck parlor-car.

2. What is the total annual maintenance-mileage of your fleet? ..... Miles.

3. What percentage of your annual maintenance-cost is represented by work done in outside shops? ..... Per Cent.

4. What percentage of your total annual maintenance-cost is work done due to accidents? ..... Per Cent. (In figuring this percentage please use the gross cost of accident repairs without any deductions for amounts recovered from insurance companies or from other parties).

5. What percentage of your annual maintenance-cost is represented by non-productive labor such as clerical help, supervision, stock clerks, and the like? ..... Per Cent.

6. What is the average number of men employed for garage service, which includes supplying gasoline, oil and water, routine inspection, tire inflation, adjustment, lubrication, and washing? ..... Men.

7. What is the average number of men employed on repair work? ..... Men.

8. If the same crew of men handle both garage and repair maintenance-work, what is the total number of men employed for this service and how is their time divided between garage service and actual repair maintenance-work? Number of men ..... Time on garage service ..... Per Cent.

9. How many hours per month do your maintenance men work? ..... Hr.

10. How many hours per month are charged to washing and cleaning? ..... Hr.

11. What are the maximum and the minimum number of maintenance men employed during the year? Maximum, ... Men. Minimum, ... Men.

During what month is the maximum number employed? .....

During what month is the minimum number employed? .....

12. What is the cost of mechanical labor per vehicle per day? $.....

What is the cost of mechanical labor per vehicle per mile? $.....

13. What is your cost of total maintenance-labor per vehicle per day? $.....

What is your cost of total maintenance-labor per vehicle per mile? $.....

14. Do you perform the following classes of maintenance in your own shop?

	Yes	No
Electrical	.....	.....
Carbureter	.....	.....
Tires	.....	.....
Radiators	.....	.....
Painting	.....	.....
Body repairs	.....	.....
Welding	.....	.....

Rebuilding complete units such as engines, axles, and the like, Yes ..... No .....

What do you consider the air-cleaner has saved in your engine-maintenance cost?
What mechanical faults have you found in the construction of air-cleaners?
What recommendations can you suggest in this field of operation?

Any information on this subject that you believe will reduce the cost of vehicle maintenance will be appreciated.

Questionnaire on Shock-Absorbers

What data have you on the flexibility and resiliency of spring design with the regulation of load control by the shock-absorber?
What is the ability of the shock-absorber to build up resistance and check rebound in proportion to the blow?
Data are desired also on:
- The ability and time-period in checking rebound
- The checking of the unresisted blow and the extraordinary force in rebound
- The original body-position without accelerated forces and the smooth rapid return with variable load-conditions
- The tension placed on springs by means of straps, springs, and the like
- The spring action as allowed by the shock-absorber

What comparative maintenance data have you on truck operation, using shock-absorbers?
What motorcoach data have you showing the advantages of shock-absorbers, variable load-deflections, and the like?

Any information on this subject that you believe will reduce the cost of vehicle maintenance will be appreciated.

Questionnaire on Oil-Filters

What type and make do you consider the most efficient?
What type and make demands the least attention?
What trouble have you had with any type?
What main trouble have you had with all types?
What percentage of saving in engine maintenance do you credit to the filter?
What percentage of your oil cost have the filters saved?
What comparative cost-data have you on bearing lubrication with filter operation?
What comparative cost-data have you on bearing lubrication without filter operation?
At what mileage or time-period do you recondition the filters?
How do you determine the condition of the oil?
What effects have you experienced with various grades of oil passing through the filtering materials?
What percentage of oil do you think the filter reclaims?
What performance have you noted in the filter with regard to its acting as a fractionating still?
What percentage of diluent content do you think is removed by the filter?
What chemical changes have you noted such as are indicated by tests for sulphuric acid (H_2SO_4) and potassium hydroxide (KOH)?
What effects have you noted from water in the filter?
What effects have you noted on the corrosive properties of filtered oil?
What effects have you noted on the temperature range of filtered oil?
Have you had any filter failures?
What was the cause of the failure?
What do you consider the average price of a filter should be on a mileage basis?
Has the oil-filter extended your overhaul period?
To what extent?
What suggestions have you to solve the filter problems?

Any information on this subject that you believe will reduce the cost of vehicle maintenance will be appreciated.

Inquiry about Committee Requirements

Mr. Wood will be glad to supply data as to the requirements of the Committee in making the study, with a view to getting cooperation from the membership and the industry at large. Requests for such information should be addressed to E. C. Wood, superintendent, transportation department, Pacific Gas & Electric Co., 445 Sutter Street, San Francisco.

The Flat-Rate-System

IT has been proved that the flat-rate method of charging for service work, when properly applied, is so far superior to the other method that there is no comparison. Flat-rate pay to the mechanic speeds up work considerably, making it possible to handle a larger volume of service business with a limited amount of floor space, and enables the good man to earn considerably more pay than when on the hour-rate or the weekly-wage basis. The slow lazy mechanic is automatically eliminated under the flat-rate plan, as he receives pay in proportion to his speed and ability and cannot make a proper wage. This method of paying mechanics reduces labor costs, even though the mechanic earns considerably more because his efficiency is increased.

The standard of workmanship is raised when mechanics are paid by the flat-rate method, since each mechanic must guarantee his work. If the service job comes back because the work was improperly done, the mechanic must do it over without compensation; hence, he is very careful to see that everything is correct. The flat-rate system represents, we feel, the most important advance in service methods that has ever been accomplished.

Fixing Flat-Rate Prices

To obtain flat-rate prices, the operation should be performed at the factory under the supervision of a flat-rate time-study engineer. After the flat-rate prices are thus set, the average time required to perform the various operations should be obtained from a representative number of dealers and a grand average of the time taken.

In arriving at a price for a service operation, we have three factors with which to contend. The cost of labor, plus overhead expense, plus profits, equals the customer's price. It is best to eliminate hours and minutes from the schedule.

To arrive at the flat-rate price to be paid the mechanic, the average hourly pay for mechanics can be obtained from a representative number of dealers. The amount of unavoidable lost time that the mechanics suffer when prompt service is given is almost universally established at 15 per cent. To establish the mechanic's flat-rate pay for any service operation, we take the average hourly rate obtained from dealers, add 15 per cent for lost time which the mechanic must absorb, and also add 10 per cent as a safety factor and to permit the average mechanic to earn more pay than he could when being paid by the hour. We then add a sufficient amount to pay overhead and make a reasonable net profit. The proper overhead percentage can be obtained from the dealers.

A study showed that the large-scale dealer has a larger overhead in proportion to volume than the dealer in a smaller city; of the amount paid the mechanic, it varied from 125 per cent for the average dealer to 170 per cent for the large-scale dealer. After adding the overhead to the mechanic's price, we then must add approximately 15 per cent for profit. The dealer in a large city should take 66⅔ per cent of the established flat-rate charge, paying his mechanics 33⅓ per cent; the average dealer should take 60 per cent, paying his mechanics 40 per cent. The price paid the mechanic, however is the same amount in dollars and cents in both cases, the difference being in the price charged the car owner.—H. M. Wiegand, director of service, Dodge Bros., Inc.

Production Engineering

Production Committee Work

Groups Are Taking Up Different Subjects and Planning Meetings

THE Production Committee of the Society, under the present organization of seven groups, is making definite progress along lines mapped out in an organization chart prepared by Chairman E. P. Blanchard.

V. P. Rumley, chairman of Group 1, on Material Handling, and his group associates, N. H. Preble and C. C. Martin, are studying the relation between volume of stock on hand and material in process, as affected by the production volume and the schedule in various plants. Mr. Rumley believes that one of the greatest savings in the present production processes, as compared with those of a few years ago, is the marked reduction of inventory and the consequent faster turnover of working capital.

Also on the schedule of this Group is a study to define the point in volume and manufacturing conditions at which it pays to change from material-handling methods that require an accumulation of stock in process, with periodic moving, to methods involving the continuous conveyor.

Chairman G. W. Blackinton has, in Group 2, on Processes and Equipment, two men who were chosen specifically for the development of proposed belting and power-transmission standards. When drafted, their proposals are to be referred to the Standards Committee for consideration and approval. This group has also for study the question of whether the Society might secure and publish descriptions of various processes established in plants throughout the industry, with the idea of furnishing a choice of methods to which production engineers might refer for suggestions applicable to their own problems. Another subject for the attention of this Group, suggested by F. T. Ellis, of the Production Advisory Board, is that of Plant Maintenance, with special attention to the control and cost of machine repairs and to plant piping and other phases of plant engineering.

Group 3, under Chairman Eugene Bouton, is taking up the further development of motion and time study. He is already in contact with Harry Ford, J. C. Mottashed and William Bayes, members of the group, on this work, and they will give attention to the various methods now established in the industry for the training of the mechanics, foremen and production engineers of the future. While the subject of Personnel Relations also comes within the scope of this group, Mr. Bouton believes that activities along this line should be held in reserve until other subjects more directly related to production and to the man on the job have been studied.

An attempt is being made this year by Group 4, on Production Expense, under H. P. Harrison, to work out a definite plan for Depreciation and Obsolescence Practice that shall prove satisfactory to the production man as well as to the accountant. In connection with this is consideration of a standardized equipment program for renewals and repairs, based on the accountant's depreciation practice, so that funds shall be more directly available for the purchase of equipment when needed. This is in line with the very interesting talk given by E. W. Weaver at last year's Production Meeting.

Several matters from other groups of the Committee will be referred to Group 5, on Production Standards. This group, under the chairmanship of L. F. Maurer, comprises the same men as the Production Division of the Standards Committee of the Society. This avoids any overlap in activities. Groups 1, 2 and 6 have suggestions that will be referred later to this group.

Group 6, under Chairman A. H. Frauenthal, is planning for an early meeting in Detroit, at which the subjects of Recommended Tolerance Practice and Methods of Inspection will be considered. The group members are interested particularly in the work being done on the standardization of Gages and Master Gages, and may find an opportunity to consider a more extensive use of fluid gages in the shops of the industry and to report on what X-ray inspection methods have to contribute. A. J. Black, of the Wright Aeronautical Corp., has been added to this group.

Guy Hubbard is the chairman of Group 7, the members of which comprise also the Production Meetings Committee covering the program and arrangements for this year's Annual Production Meeting on Nov. 22 and 23. Other work of the group is the developing and indicating of points of contact between design and production engineers, and attempting to make the programs and papers of the Society of a sort that will be of as great interest to the production engineers of small plants as to those who are operating on a larger-quantity basis.

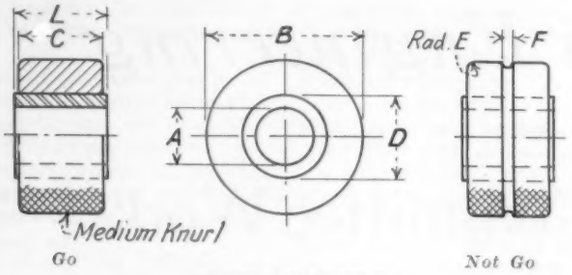
Each of the various groups expects to make a progress report on its work at the Production Meeting, and the plans now being formulated for the program for that meeting promise some of the most interesting sessions in recent years. The Production Committee is showing definite progress, and virtually every member is charged with the responsibility of reporting on one or more of the phases of its work. The chairman believes that marked progress and constructive results will be obtained during the year.

Plain Ring-Gage Blanks

Criticism of Specification Is Invited Pending Its Adoption as S. A. E. Standard

AT the time the American Gage-Design Committee was working on the standardization of blanks for cylindrical and threaded plug-gages and ring thread-gages, which have been reported in previous issues of THE JOURNAL, a standard was also being drafted for plain ring-gages. The Production Division of the Society's Standards Committee has been following this work closely, and recommended at the Standards Committee meeting at Quebec in June that the reports on cylindrical and threaded plug-gages and ring thread-gages be adopted as S.A.E. Recommended Practice.

Since the meeting of the Standards Committee, the following specification for plain ring-gage blanks has been submitted to the Society by D. W. Ovaitt, Chairman of the Technical Subcommittee of the American Gage-Design Committee. The report is published for the information of members



PLAIN RING GAGES

Gage Size	Range A Above	Range A including	B ± 0.010	C ± 0.010	D[1]	Radius E	Groove F	Bushing L
00	0.059	0.150	15/16	3/16	3/8	1/32	1/32	1/4
0	0.150	0.240	15/16	3/8	7/16	1/32	1/16	7/16
1	0.240	0.365	1 1/8	9/16	9/16	1/16	3/32	5/8
2	0.365	0.510	1 3/8	3/4	3/4	1/16	3/32	13/16
3	0.510	0.825	1 3/4	15/16	—	3/32	3/32	1
4	0.825	1.135	2 1/8	1 1/8	—	3/32	3/32	1 3/16
5	1.135	1.510	2 1/2	1 5/16	—	3/32	3/32	1 3/8

Materials.—Shells of sizes Nos. 00 to 2, inclusive, to be of cold-rolled steel; gages of size No. 3 and larger to be of hardened tool-steel.

[1] Tolerance on hole for bushing, +0.000, —0.005 in. Bushing diameter, D+0.020 in., to allow for fitting. No bushing used in sizes No. 3 and larger.

before the Production Division acts on it. The Division feels that any constructive criticism of the report that members may wish to make should be forwarded to the Society's Standards Department promptly. All such comments will be summarized and referred to the Division prior to any action it may take as to recommending the adoption of the report by the Society as one of its standards, probably at the Annual Meeting next January.

The report relates only to blanks for the gages, the finished gaging-dimensions being left to the requirements of the gage purchasers or users. The blanks provide for gaging pieces up to and including 1½-in. nominal diameter, the ranges of the gage sizes corresponding to those in the report on cylindrical and threaded plug-gages, published in this issue of THE JOURNAL, p. 208. The "Not Go" gages are distinguished by a groove.

Depreciation and Obsolescence

WEAR and tear, or depreciation, is a scientific measurement and can be determined accurately in cost accounting. Obsolescence is analogous to fire as a risk. It cannot be determined any more than the date a building will burn can be determined. An arbitrary basis of accounting for the two factors does justice to neither, and fails in adequately providing a fund for replacing machinery when its value has been destroyed by its being worn out or rendered obsolete.

If obsolescence is defined as representing the dead line beyond which a machine cannot compete profitably with another machine, none of the machine's value is destroyed until the dead line is reached; then the value is destroyed all at once. Depreciation approaches its dead line by gradual and constantly diminishing value. Therefore, the two cannot accurately be lumped.

Natural caution and economy prompt us to retain methods and equipment long after the period of their greatest usefulness or profitableness. Facts and information are probably the greatest factors for providing the assurance and courage necessary to discard the obsolete and inaugurate the new. At present, no facts or information seem available to the public generally. Some of the most ingenuously managed concerns have data and policies concerning obsolescence, but this only accentuates the inability of others to continue satisfactory profits. The market price established by the most efficient is a difficult goal for the less efficient to achieve. Probably the most stabilizing and most profitable competitive condition is when all are as efficient as the most efficient. Therefore, whatever can be done to approach this end should have practical value.

It seems that there are two important phases of industrial-equipment study; one to bring out facts that show obsolescence to be an important factor in production costs; and another, which should follow as a natural consequence, the importance of correctly evaluating and providing for obsolescence in cost accounting.

The first result would probably best be attained by a comprehensive study among manufacturers of machinery of the history of specific machines; such as milling-machines and planers. A study of the milling-machine, for instance, would likely show an important development or improvement on an average of every so many years. Perhaps a study of the manufacturer's sales records would reveal whether a machine was purchased to replace one that had become inadequate by obsolescence or by depreciation. These developments would be studied for the further purpose of determining the standard, under the various conditions of production, against which machines could be measured for obsolescence.

The second phase of the study would involve the enumeration of the machines in the users' plants of whatever industry or industries selected. The census of the machines in use would probably include such questions as the type, model, and size of the machine; floor space occupied; productivity and age of the machine; power consumption; repairs; and rejects of its product. These items are tentative as yet.

The outcome of the industrial-equipment survey proposed by the Department of Commerce depends, of course, largely upon our success in obtaining basic information. If some basis could be developed upon which to provide for insurance against the hazard of obsolescence, the value of the study would undoubtedly more than justify the efforts of the Department and the cooperation of those from whom data must be obtained. Such result would probably be an important contribution toward the stabilization of American prosperity.—From a Bulletin of the Department of Commerce.

Uses of Aluminum

PRODUCTION engineers who have occasion to use aluminum alloys will be interested in the paper by R. S. Archer, appearing in this issue beginning on p. 149. In this paper Mr. Archer tells something of the progress in fabrication of aluminum alloys and gives an idea of the extent to which their utilization has been extended. Present limits of size in castings, forgings and rolled sections are indicated, and the gains to be realized by substituting the lighter material are outlined.

Personal Notes of the Members

Honorary Degree for Kettering

C. F. Kettering, Vice-President of the General Motors Corporation, has been made Honorary Doctor of Engineering by the University of Michigan in recognition of a "public benefactor, a great engineer and an inventor of the highest scientific attainment." The citation further adds that his invention of starting, lighting and ignition devices, known as the Delco system was an important contribution to the automotive industry. The complete system of cranking, lighting and ignition quickly followed the development of his first generator system of ignition, which was adopted by the Cadillac Motor Car Co., and in the summer of 1911 the first Delco-equipped car appeared on the market. The degree of Doctor of Science also was conferred upon him recently by the University of Cincinnati.

A most familiar figure to all concerned with Society affairs, Mr. Kettering, who held the Presidency of the Society in 1918, has ably filled many committee offices since his election to membership in 1911. He served for five successive years on the House Committee, acting as Chairman of this Committee in 1919 and 1923, and has been a Research Committee member for several years. He has been a member of various other committees, among them, the Simplified Practice Committee, the Electrical Equipment Division and the Lighting Division of the Standards Committee. He is the author of numerous articles, embracing a wide range of valuable engineering and scientific data, which have been published in THE JOURNAL and the TRANSACTIONS.

E. W. Templin's New Position

E. W. Templin has resigned as chief engineer of the Six Wheel Co. at Philadelphia, to take charge of the National fleet of trucks for the Mavis Bottling Co. of America, whose headquarters are in Baltimore. He joined the engineering staff of the Six Wheel Co. in 1925. Prior to establishing this connection, he was successively associated with the Selden Motor Vehicle Co. and the Goodyear Tire & Rubber Co.

Mr. Templin joined the Society in 1918 and the Cleveland Section in 1921, transferring his Section membership to Pennsylvania in 1925 when he entered upon his affiliation with the Six Wheel Co. His membership in the Society has been marked by a cooperative spirit and constructive service. During the last four years, as a member of the Motorcoach Division of the Standards Committee, he has contributed valuable support to the work of this Division. He has also been prominent in Section affairs, having been elected Treasurer of the Pennsylvania Section in 1925 and Chairman of the Section the following year. This year he is a member of the Council and of the Sections Committee of the Society.

Valuable contributions to THE JOURNAL have been made by Mr. Templin in the form of articles entitled Highway Transportation as it Affects the Automotive Engineer, published in 1922 in the March issue of THE JOURNAL and Part I of the TRANSACTIONS for that year, and What Motor Trucks Need To Supplement Pneumatic-Tire Development, appearing in the October, 1920, issue of THE JOURNAL.

Parker Joins Bendix Co.

Humphrey F. Parker has severed his connection with the Federal Burner Corporation at Bridgeport, Conn., where he acted as experimental engineer, to accept a position as research engineer for the Bendix Brake Co., South Bend, Ind.

A great part of Mr. Parker's engineering experience has been devoted to the field of aeronautics. His first connection with the aeronautical industry dates back to 1915, when he assembled seaplanes while in the service of the Sopwith Aviation Co., and England. He left this position during the war to join the Royal Naval Air Service as an airplane pilot, and later came to America to take up the duties of assistant engineer physicist in the Bureau of Standards. He returned to England in 1922, only to come back to the United States the next year as assistant physicist at the Naval Aircraft Factory at Philadelphia.

Elected a Member of the Society in 1921, Mr. Parker has since been an interested participant in its affairs. He is the author of two very interesting papers on the subject of aeronautics; one is Water Recovery for Airships, published in the December, 1924, issue of THE JOURNAL as well as in Part II of the 1924 TRANSACTIONS, and the other is Airplane and Airship: Their Spheres of Economic Usefulness, published in the February, 1926, issue of THE JOURNAL.

E. C. Wood on Garage Committee

E. C. Wood, superintendent of the transportation department for the San Francisco division of the Pacific Gas & Electric Co., has been appointed a member of the Garage Committee of the National Electric Light Association.

Since his election to Member grade in the Society in 1925, Mr. Wood has been actively identified with the Northern California Section. He was chosen the first chairman of the newly organized Section in 1925, and was re-elected to office the following year. This year he is serving as Vice-Chairman of the Operation & Maintenance Committee. Many articles on garaging and maintenance have appeared under his name in various publications. Motor-Trucks on the West Coast is the title of a maintenance paper presented by Mr. Wood at the 1927 Transportation Meeting of the Society and published last March in THE JOURNAL.

Edison Honored by A. I. E. E.

Thomas A. Edison, famous inventor, was elected Honorary Member of the American Institute of Electrical Engineers at a meeting of its board of directors held in Denver, June 27, during the annual summer convention of the Institution. Mr. Edison, whose achievements in the scientific world are universally known and too numerous to permit their mention in these columns, was one of five distinguished American engineers to be so honored.

Mr. Edison has been connected with the Society of Automotive Engineers since 1911, when he was elected a Member.

E. S. Marks Sailing for Europe

E. S. Marks, chief engineer of the H. H. Franklin Mfg. Co., expects to sail for Paris during the latter part of September to attend the Paris Automobile Salon and to study general automotive trends in Europe. He plans to visit several well-known automobile factories on the Continent and to return to London in time for the Olympia Show. Mr. Marks has been associated with the Franklin Company since 1917, when he joined it in the capacity of laboratory assistant, later becoming experimental engineer, assistant chief engineer and, in 1925, chief engineer.

Mr. Marks has been a Member of the Society since 1922 and became a Buffalo Section member this year. He has taken a prominent part in Society affairs, having been especially active during the past three years in Standards Committee work. He has taken a no less active part in research matters, having served for two successive years on the Headlight Subcommittee.

(*Continued on p.* 34)

Morris M. Titterington

A BRILLIANT career in the field of aeronautic engineering was brought to an untimely and tragic end when, on July 11, an airplane crashed on a mountain side near Snyders, among the mountains of eastern Pennsylvania during a thunderstorm. Morris M. Titterington, vice-president and chief engineer of the Pioneer Instrument Co., of Brooklyn, N. Y., who was piloting the craft, and Mrs. Bernice Gamble Andrews, of Williamsport, Pa., his companion on the flight from Curtiss Field en route to Dallas, Tex., met instant death in the disaster, according to the statement of physicians who were summoned by a farmer on whose land the airplane fell. The storm made visibility poor and caused strong and treacherous winds. It was believed that lightning struck the airplane.

It seems an irony of fate that Mr. Titterington, who had devoted the last 14 years to the study, design and construction of navigation instruments to increase the safety of aviation, should meet such an end. His early experience in learning to fly, at Hammondsport, N. Y., while working as a mechanic on engine assembling and testing and as a draftsman on airplane details for the Curtiss Aeroplane & Motor Co. during 1913 and 1914, showed him the need for better instruments than then existed for enabling aviators to fly with safety in bad weather. Going to New York City in 1914, he entered the laboratories of the Sperry Gyroscope Co., where he worked on detail designs of the Sperry gyroscopic stabilizer and installed, adjusted and demonstrated the system. During the World War he spent 3 years in England for the company, designing and installing airplane instruments and equipment, including gyroscopic devices and bomb sights. Returning to this Country in 1917, he had charge of development work for the Sperry Company on an aerial torpedo, until the armistice, and then designed a ship's log for marine use.

In 1920 Mr. Titterington, Charles H. Colvin and Bryce Goldsborough, all then connected with the Sperry Company, organized the Pioneer Instrument Co., of Brooklyn, Mr. Titterington having charge of all development work on aircraft instruments. In this capacity, his most recent and notable invention was the earth-inductor compass, which has been such an essential aid to all recent transoceanic flights, including those of Lindbergh, Commander Byrd, and Chamberlin.

Mr. Titterington was only 37 years of age, having been born at Paris, Tex., on July 20, 1891. He was elected to Member grade in the Society in November, 1926, and later became a member of the Metropolitan Section. He was also a member of the American Society of Mechanical Engineers. The inductor compass of which he was the inventor was illustrated and described in a paper on Aircraft Instruments for Oversea Navigation, by Victor E. Carbonara, published in THE JOURNAL for November, 1927, p. 528.

Hugo C. Gibson

AFTER an illness of 4 months, Hugo C. Gibson, consulting engineer of Philadelphia, passed away at his home on July 6 and the funeral was held on July 9. Mr. Gibson is survived by his widow, Mrs. Margaret A. Gibson; a daughter, Margaret; and a son, Charles.

Mr. Gibson was a native of England, having been born at Malvern Link in 1874. Following his preparatory education at the City of London School, he received his technical education in the City and Guilds of London, Finsbury. Coming to America, he engaged in consulting engineering practice and served the Association of Licensed Automobile Manufacturers, a predecessor of the present National Automobile Chamber of Commerce, from 1906 to 1909 in that capacity.

Elected to membership in the Society in June, 1910, with the grade of Associate but transferred the following month to Member grade, Mr. Gibson was one of the very early members and retained his membership for 18 years to the end of his career. He was well known to the founders and other early-day members, including E. T. Birdsall, A. L. McMurtry, Alexander Churchward, Henry Hess, Joseph Tracy and H. C. Cave, and was a member of the Pennsylvania Section. In 1921 he was a member of the Stationary Engine Division of the Standards Committee.

A paper on The Manograph, by Mr. Gibson, was published in THE BULLETIN, April, 1913, and in TRANSACTIONS, 1913, Part 1, p. 237; and another entitled Bettering the Efficiency of an Existing Engine was published in THE JOURNAL for January, 1920, p. 7, and in TRANSACTIONS, 1920, Part 1, p. 177. At what probably was the last meeting of the Society attended by Mr. Gibson, he made a contribution to the discussion of C. A. Atwell's paper on gas-electric drives for motorcoaches, when it was presented in Philadelphia. His discussion appears on p. 195 in this issue of THE JOURNAL.

Benjamin Needham Jones

AS the result of an illness of a month's duration, Benjamin N. Jones, equipment engineer of the Otis Elevator Co., of New York City, passed away on July 4 at his home in Glen Ridge, N. J. He is survived by his widow, Mrs. Bessie Jones; a son, Benjamin; and four daughters, the Misses Elizabeth, Margaret, Agnes and Katherine Jones.

Mr. Jones was a native of New Jersey, having been born at Somerville on April 1, 1871, and received his technical training at the Stevens School and Institute in Hoboken.

From 1894 to 1898 he was engaged in construction work for the Sprague Electric Elevator Co., and during the following 2 years in engineering and construction work for the Otis Elevator Co., of New York City. He was electrical and mechanical engineer for the Marine Engine & Machine Co., of Harrison, N. J., from 1900 to 1905, and then returned to the Otis Elevator Co. as assistant manager of the manufacturing department.

At the time of his election to Member grade in the Society in 1916, Mr. Jones held the position of engineer in the industrial department of the Otis Company, where his work included the designing of automobile parts. His service with this company therefore extended over a period of 25 years. Prior to his election to the Society, his automotive engineering experience included the designing and building of four automobiles for his personal use during the years 1911 to 1914 and the designing of a line of worm-drive axles for commercial cars.

Mr. Jones was a member of the American Institute of Electrical Engineers since 1903 and of the American Society of Mechanical Engineers since 1904.

George A. Giroux

THROUGH the very premature passing away, at the age of 32, of George A. Giroux, senior inspector of aircraft for the Navy, aeronautics and the Society have suffered the loss of a competent young engineer in a branch of automotive engineering that can ill spare its promising young men at a time when it is developing so rapidly.

Mr. Giroux was born at Providence, R. I., in February, 1896, and, after progressing through the grammar school and 2 years of high school and devoting much time to constant home study, he secured appointment in 1918 as assistant inspector of engineering material in the Brooklyn aeronautic district for the United States Navy and continued to serve the Navy in this capacity and as an inspector of naval aircraft and aircraft construction up to the time of his regretted demise on June 24.

During his 10 years of service he was stationed successively at the plants of the Aeromarine Plane & Motor Co., at Keyport, N. J.; the Goodyear Tire & Rubber Co., in Akron, Ohio; the Curtiss Aeroplane & Motor Corporation, at Garden City, N. Y.; Huff, Daland & Co.; the Wright Aeronautical Corporation, Paterson, N. J.; and the Loening Aeronautical Engineering Corporation, New York City. The duties of his of-

fice as inspector-in-charge during the last 6 years required much executive ability as well as an intimate knowledge of sound aeronautic engineering and manufacturing practice.

Mr. Giroux had been a member of the Society since his election to Member grade in March, 1926, and was also a member of the Metropolitan Section. He was married and lived in Brooklyn, N. Y.

Joseph Allison Steinmetz

WITH the lamented passing of Joseph A. Steinmetz at his home in Germantown, Pa., on July 11, after a long illness which caused his retirement from business activities 6 months previously, the automobile and aeronautic industries have lost another of their pioneers and the Society an Associate Member of 16 years' standing.

Besides his many contributions of inventions in the fields of automobile and aeronautic engineering, dating from the beginnings of both industries, Major Steinmetz was the inventor of various anti-aircraft devices during the World War, including the Steinmetz hook-bomb which was adopted by the French army for use in repelling attacks by Zeppelins, a plan of lights and anti-aircraft guns for luring hostile airplanes within the range of fire, and a balloon designed to rise to a great height and to explode upon contact with an airplane. When the United States entered the war, Major Steinmetz was appointed a member of the National Research Council and toured France and England to study the progress of the Allies in airplane construction.

Major Steinmetz was best known in the automotive industry as a member of the firm of Janney, Steinmetz & Co., of Philadelphia, from the date of its organization in 1893, and for his work as a designer and patentee of seamless-steel shapes, drawn-steel gasoline and air-pressure tanks, the application of aluminum to the arts and sciences, and his development of the compressed-air engine-starter.

Born in Philadelphia in 1870, Mr. Steinmetz received his education in the Central High School in that city and in Lehigh University. Subsequently he became associated with the Aluminum Co. of America as an expert in the application of aluminum to commercial uses, but had devoted his attention to the interests of Janney, Steinmetz & Co. for the last 35 years. He was elected to Associate membership in the Society in 1912, and was a member also of the Pennsylvania Section, the American Electrochemical Society, the Aero Club of America, the Franklin Institute in Philadelphia, the Army and Navy Club of New York City, the Colonial Society of Pennsylvania, the Pennsylvania Society of the Sons of the Revolution, the Motor & Accessories Manufacturers Association, the National Association of Engine & Boat Manufacturers, the Engineers Club of Philadelphia and the Aero Club of Pennsylvania.

Mr. Steinmetz is survived by his widow, Mrs. Norma Frances Steinmetz; a son, Joseph A. Steinmetz, Jr.; and a daughter, Frances Margaret Steinmetz.

Charles A. Chevraux

IN the passing of Charles A. Chevraux the industry has suffered the loss of an expert of long experience in the design and manufacture of vehicle springs. For 30 years Mr. Chevraux devoted his efforts to the making of springs, first for horse-drawn vehicles and later for automobiles and motor-trucks as well. Twenty-four of these years were spent in the manufacturing and executive departments of the Cleveland-Canton Spring Co., of Canton, Ohio, for which he designed springs and of which he was secretary for many years.

Mr. Chevraux was born in Canton in 1877 and lived in that Ohio city virtually all his life. His business career began at the age of 15, in 1892, when he started work as a machinist with the Novelty Iron Co., of Canton. Two years later he went to the Columbia Spring Co., of the same city, and, after 3 years there, entered the traffic department of the Pennsylvania Railroad Co. After 4 years with the railroad he returned to the spring business, joining the Cleveland-Canton Spring Co. in 1901. Twenty-four years later he became production manager of the Jenkins Vulcan Spring Co., at Richmond, Ind., subsequently going to Massillon, Ohio, as secretary of the Bean Spring Co., then returning to his home city as secretary, treasurer and general manager of the Canton Bolt Co.

In the latter part of June Mr. Chevraux received injuries while inspecting machinery at the plant of the bolt company, which resulted in his death on July 6 at Mercy Hospital. He is survived by his widow, his father, four brothers and a sister.

He had been an Associate Member of the Society for 14 years, since his election in 1913, and was a member of the Cleveland Section.

George E. Wedin

FOLLOWING an illness of 6 months' duration, life ceased for George E. Wedin at Jamestown, N. Y., on July 3, to the sincere regret of his associates in the engineering department of the Springfield, Ohio, plant of the International Harvester Co., as well as the bereavement of his four surviving sisters.

After 10 years' prior experience in mechanical lines, Mr. Wedin had been engaged in experimental and service engineering work for the last 8 years with the Harvester Company, the first half of the period at the Akron plant and the last 4 years as assistant engineer at Springfield, where he was in charge of design on motorcoaches.

Born at Carrollton, N. Y., in 1894, Mr. Wedin acquired his education in the public schools and through the engineering course of the International Correspondence School. At the age of 16 he became an apprentice with the Jacobson Machine Mfg. Co., of Warren, Pa., and after 3 years joined the Warren Axle & Tool Co. as a diemaker. In the same capacity he served the Remington Arms Co. at Eddystone, Pa., during 1916 and 1917; then entered the Buffalo plant of the Curtiss Aeroplane Corporation as a toolmaker. During the next 3 years he served as toolmaker and foreman, first with the American Brake Shoe & Foundry Co. and then with the General Electric Co. at Erie.

It was in 1919 that Mr. Wedin formed his connection with the International Harvester Co., going to Akron to do experimental engineering work.

In May, 1924, Mr. Wedin was admitted to Junior Membership in the Society, and in December of the same year was transferred to Member grade.

Applicants for Membership

The applications for membership received between June 15 and July 16, 1928, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BAKER, WILLIAM HENRY, president, Baker Machinery Co., *Des Moines, Iowa.*

BARLOW, LESTER P., consulting experimental engineer, McCord Radiator & Mfg. Co., *Detroit.*

BEAUMONT, EUGENE GUY EUSTON, motor superintendent, Anglo American Oil Co., Ltd., *London, S. W. 1, England.*

BRACKETT, C. L., president and manager, National Machine Products Co., *Detroit.*

BURT, CLYDE A., owner and manager, Clyde A. Burt, *Los Angeles.*

BUSEY, ROBERT E., student engineer, Packard Motor Car Co., *Detroit.*

CAMPBELL, DONALD M., sales engineer, Aluminum Co. of America, *Detroit.*

CARPENTER, IRVIN A., brake service manager and owner, Electro Brakometer Super Service, *San Francisco.*

CATELLIN, GASTON J. L., service manager, Brownback Motor Laboratories, Inc., *New York City.*

CROMWELL, CHARLES O., sales engineer, Rollway Bearing Co., *Syracuse, N. Y.*

DEANGELES, A. C., machine layout and design, Eclipse Machine Co., *East Orange, N. J.*

DECROW, V. R., vice-president, Decrow Automotive Specialties, Inc., *Lockport, N. Y.*

DELEHANTY, RICHARD J., body designer, Durant Motors, Hayes Hunt Division, *Elizabeth, N. J.*

DESCHAMPS, DESIRE J., technical manager, Minerva Automobiles, Inc., *New York City.*

DUNN, RAYMOND E., layout draftsman, Chevrolet Motor Co., *Detroit.*

DUSTON, FREEMAN C., assistant editor, Industrial Press, *New York City.*

EGER, ERNEST, development engineer, United States Rubber Co., *Detroit.*

ELLIOTT, FRANK R., field engineer, Ethyl Gasoline Corporation, *New York City.*

ENGELMANN, BERT R., special representative, Simplex Piston Ring Co. of America, Inc., *Cleveland.*

FRANTZ, EMERSON, sales engineer, Bohn Aluminum & Brass Corporation, *Detroit.*

FREY, OSCAR, organizing a new body company, 333 West Wayne Street, *Lima, Ohio.*

GREENE, PHILIP D., research engineer and chemist, The Asbestos Textile Co., *North Brookfield, Mass.*

GROH, JULIUS A., body engineer, Ceskomorauska-Kolben-Danek, *Prague, Czechoslovakia.*

GRUMME, JOSEPH WILLIAM, JR., specification engineer, American LaFrance & Foamite Corporation, *Elmira, N. Y.*

GUNNING, C. H., service manager, Bresee Chevrolet Co., *Syracuse, N. Y.*

HOSPERS, JOHN J., manager and instructor, New Jersey Flying Service, *Bayonne, N. J.*

KINNEAR, HARRY T., chief draftsman, Splitdorf Electric Co., *Newark, N. J.*

KUBAT, ANTONIN O., manufacturing manager, Ceskomoravska - Kolben - Danek, *Prague, Czechoslovakia.*

LEWIS, OSCAR B., sales representative, Ethyl Gasoline Corporation, *New York City.*

LOCKWOOD, RALPH G., executive engineer, Fairchild Aviation Corporation, *Farmingdale, L. I., N. Y.*

LOOMIS, BYRON B., sales engineer, McGill Metal Co., *Valparaiso, Ind.*

MAHONEY, BURTON, engineer, Vacuum Oil Co., *New York City.*

MAHONEY, J. ALLAN, engineer, Vacuum Oil Co., *New York City.*

MARSHALL, FURBER, president and general manager, National Brake Service, Inc., *Chicago.*

MCWHIRTER, L. D., motor mechanic, L. C. Buxton, *Los Angeles.*

MUELLER, C. W., sales engineer, Universal Foundry Co., *Oshkosh, Wis.*

NORDBERG, BRUNO V. E., executive engineer, Nordberg Mfg. Co., *Milwaukee.*

NULSEN, JOHN C., vice-president and general manager, B. F. Mahoney Aircraft Corporation, *San Diego, Cal.*

POSNER, HARRY, president, Posner Brake Lining Service, Inc., *Newark, N. J.*

POSNER, SAMUEL, secretary and chief engineer, Posner Brake Lining Service, Inc., *Newark, N. J.*

PROCTOR, RALPH D., efficiency engineer, M. P. Miller Motor Car Co., *Hagerstown, Md.*

RANDLES, JOHN THOMAS T., works director, Dunlop Rubber Co., *Birmingham, England.*

REID, HENRY J. E., engineering in charge, Research Laboratory, *Langley Field, Va.*

ROBBINS, MAX B., engineer, draftsman, Delta Electric Co., *Marion, Ind.*

ROTHERMEL, ROYDEN ALBERT, managing director, The Rothermel Corporation Ltd., *London, W. 1, England.*

SAXON, ARTHUR H., chief engineer, Lincoln Aircraft Co., *Lincoln, Neb.*

SHERWOOD BROTHERS INC., *Baltimore.*

SHOCKEY, NEWTON E., assistant general manager, L. A. Young Spring & Wire Corporation, *Detroit.*

SIERS, ALPHONSE, checker, Timken Detroit Axle Co., *Detroit.*

TANNER, ROBERT HOWARD, lubrication engineer, Imperial Oil Co., *Montreal, Que., Canada.*

TANNEWITZ, EDWARD F., president and general manager, Detroit Cord Mfg. Co., *Detroit.*

TOBOLDT, WILLIAM KING, assistant technical editor, *Automobile Trade Journal*, Chilton Class Journal Co., *Philadelphia.*

TUCEK, JERRY, service manager, Ceskomoravska-Kolben-Danek, *Prague, Czechoslovakia.*

VAN DER SPUY, A. J. N., mechanic and electrician, Hupp Garage (Cape), *Cape Town, South Africa.*

VOLKMAR, WALTER HERBERT, general superintendent, Emerson-Brantingham Corporation, *Rockford, Ill.*

WOLFF, EWALD J., mechanical engineer, General Motors Corporation Research Laboratories, *Detroit.*

WOODYARD, ROY MELVIN, service and testing, Murphy Motors, *Los Angeles.*

YANCEY, STIRLING ROSS, president, general manager, Sure-Guard Corporation, *New York City.*

Applicants Qualified

The following applicants have qualified for admission to the Society between June 9 and July 10, 1928. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALLEN, OLIVER FIELD (M) manager automotive sales, International General Electric Co., Inc., 1 River Road, *Schenectady, N. Y.*

ALLYN, HAROLD M. (M) general supervisor of motor vehicles, Ohio Bell Telephone Co., 750 Huron Road, Cleveland; (mail) 1231 Lakeland Ave., *Lakewood, Ohio.*

ARLINGHAUS, FRANK HENRY (J) sales engineer, Hyatt Roller Bearing Co., Harrison, N. J.; (mail) 209 Jane Street, *Weehawken, N. J.*

ATHERTON, HAROLD S. (A) district manager in charge of car equipment business, Whitaker Battery Supply Co., Kansas City, Mo.; (mail) 1625 Greenleaf Avenue, *Chicago.*

BASTIEN, PAUL (M) engineer, in charge of engineering, Stutz Motor Car Co., *Indianapolis;* (mail) 4046 Central Avenue.

BEVAN, MAJOR WILLIAM A. (M) assistant professor of mechanical engineering, in charge of aeronautical engineering courses, Purdue University, Lafayette, Ind.; (mail) 113 Waldron Street, *West Lafayette, Ind.*

BINYON, ALGERON HAMO (M) Laneside, 227 Kingshighway, *Westport, Conn.*

BLAKELEY, G. B. (A) New York export representative, White Motor Co., 225 Broadway, *New York City.*

BRENTLINGER, OWEN J. (A) dynamometer test, Hupp Motor Car Corporation, *Detroit;* (mail) 5757 Lenox Avenue.

BROWN, GILNOR H. (A) Oakland Motor Car Co., Room 911, City Center Building, 121 North Broad Street, *Philadelphia.*

BROWN, PERCY A. (M) supervisor of inspection, Graham-Paige Motors Corporation, *Detroit;* (mail) 1967 LaMoth Avenue.

CLEMENS, JOHN W. (M) chief engineer, in charge of truck design and production, Patriot Mfg. Co., Eighth and M Streets, Havelock, Neb.; (mail) 634 South 33rd Street, *Lincoln, Neb.*

CLEMENTS, HUBERT INGHAM (A) automomobile engineer, H. I. Clements, 2 McLachlan Avenue, Rushcutter's Bay, *Sydney, N. S. W., Australia.*

CONNAL, W. F. (M) mechanical engineer, Canadian National Railways, *Montreal, Que., Canada;* (mail) 360 McGill Street.

CONNELLY JAMES MAURICE (J) metallurgist, chemist, Electric Refrigeration Corporation, Plymouth Road, *Detroit;* (mail) 13530 Monte Vista Avenue.

CORD, E. L. (A) president, Auburn Automobile Co., *Auburn, Ind.*

DILG, EARL W. (M) Evans-Wiltse Corporation, care Midwest Tool Co., Detroit; (mail) 4722 Orchard Boulevard, *Fordson, Mich.*

DREBING, ELMER CHARLES (M) master mechanic, Calumet Coal Co., 9022 Commercial Avenue, *South Chicago;* (mail) 8108 Bennett Avenue.

ELLIOTT, COURTNEY G. (A) service manager, Sonoma Motor Sales Co., 639 Wall Street, *Los Angeles.*

FARNSWORTH, WAYNE HEATHCOTE (J) testing and experimental engineer, Hall-Scott Motor Car Co., *Berkeley, Cal.*

FOWLER, WILLIAM JAMES (A) draftsman, Edward G. Budd Mfg. Co., *Detroit;* (mail) 59 Seward Avenue.

FREE, FRANK (M) Alexander Aircraft Co., *Denver, Colo.*

FREY, ALBERT E. (M) chassis engineer, Studebaker Corporation of America, *Detroit;* (mail) 4153 Elmwood Avenue.

GILMORE, DONALD FOSTER (A) service manager, Sands Motor Co., 1024 East Pike Street, *Seattle, Wash.*

GRANT, RUDOLPH R. (M) president, chief engineer, Dayton Airplane Engine Co., 1323 Third National Bank Building, *Dayton, Ohio;* (mail) 1246 Leo Street.

GRIFFIN, NICHOLAS M. (A) vice-president, Mack-International Motor Truck Corporation, *Chicago;* (mail) 3300 Wentworth Avenue.

GROEHN, OTTO J. (M) superintendent, Gratiot Plant, Hudson Motor Car Co., 10617 Knodell Avenue, *Detroit.*

HANDLER, EUGENE (M) vice-president, treasurer, general manager, Lyons Storage Battery Co., 218 Washington Street, *Belleville, N. J.*

HOMS, JOSE M. (A) export manager, Pablo Homs, Inc., 44 Whitehall Street, *New York City.*

HUTCHISON, ROBERT R. (M) in charge of engine division, engineering department, Oakland Motor Car Co., *Pontiac, Mich.*

JAMES, WILLIAM M. (A) works manager, Kearney & Trecker Corporation, West Allis, Wis.; (mail) 3027 Wisconsin Avenue, *Milwaukee.*

JOHNSON, GEORGE D. (J) partner, Gas & Oil Engine Service Co., 30-70 Eighth Avenue, *Long Island City, N. Y.*

JURZEK, LEON J. (M) factory manager, lamp plant, Ford Motor Co., Dearborn, Mich.; (mail) 326 W. Lewiston Avenue, *Ferndale, Mich.*

KELLEY, JOHN P. (A) sales manager, automobile division, A. O. Smith Corporation, 27th Street and Keefe Avenue, *Milwaukee.*

KIRK, J. N. (A) sales and advertising manager, World Bestos Corporation, 52 Courtland Street, Paterson, N. J.; (mail) New York Athletic Club, 58 W. 59th Street, *New York City.*

KNUTH, WILLIAM C. (A) owner, The Knuth Co., 2525 Fond du Lac Avenue, *Milwaukee.*

LANE, H. S. (A) manager of sales, wholesale and retail, Garford Motor Truck Co., Inc., 3210 Spring Garden Street, Philadelphia; (mail) Knox and Forrest Roads, *Wynnewood, Montgomery County, Pa.*

LUKENS, H. M. (J) draftsman, Graham-Paige Motors Corporation, *Detroit.*

MACNALLY, MAXWELL F. (J) sales engineer, S K F Industries, Inc., 517 Manufacturers and Traders Building, *Buffalo;* (mail) 2255 Delaware Avenue, Apartment C-2.

MAULSBY, F. R. (M) superintendent motor-vehicle equipment, American Railway Express Co., 635 Folsom Street, *San Francisco.*

MCCANDLESS, M. LOWRIE, JR. (J) specification engineer, Chandler-Cleveland Motors Corporation, 8217 Carnegie Avenue, *Cleveland.*

MCCLELLAN, STEPHEN A. (J) sales engineer in charge of commercial sales, Pratt & Whitney Aircraft Co., *Hartford, Conn.;* (mail) University Club.

MCCORMICK, CHARLES ELLSWORTH (M) trim engineer, selling, Vogt Mfg. Corporation, 10-233 General Motors Building, *Detroit;* (mail) 843 Whitmore Road.

MORSS, CHARLES ANTHONY (M) experimental test engineer, Wright Aeronautical Corporation, 238 Lewis Street, Paterson, N. J.; (mail) 91 Lloyd Road, *Montclair, N. J.*

MORVAY, ANTON ALLAN (J) airplane engineer, designer, chief engineer, American Aircraft Corporation, 3011 South Wabash Avenue, *Chicago;* (mail) 832 North California Avenue.

MOSTHAF, EDWIN FREDERICK (J) chief engineer, Wright Flexible Axle Motor Car Co., 798 St. Catherine Street, *West Montreal, Quebec, Canada.*

NARDONE, ROMEO M. (J) draftsman, designer, Eclipse Machine Co., East Orange, N. J.; (mail) 323 Park Avenue, *Newark, N. J.*

PINNER, W. L. (J) chemical engineer, C. G. Spring & Bumper Co., 2660 East Grand Boulevard, *Detroit.*

PRATHER, GEO. W. (A) inventor, owner, manufacturer, Prather Mfg. Co., 323 Front Street, *Santa Cruz, Cal.*

PROCTOR, GEORGE WILLIAM (M) chief draftsman, production, Chevrolet Motor Co., 7-153 General Motors Building, *Detroit.*

RICHARDS, HOWARD R. (A) development engineer, Cleveland Tractor Co., *Cleveland;* (mail) 13501 Rugby Road.

RITTER, JACOB J. (M) sales, engineering, New Britain Machine Co., New Britain, Conn.; (mail) 2-130 General Motors Building, *Detroit.*

RUEHLMANN, LOUIS E. (M) body engineer, Edward G. Budd Mfg. Co., Charlevoix Street, *Detroit.*

SAGER, RUSSEL (A) experimental work on gears and cams, General Motors Corporation Research Laboratories, *Detroit;* (mail) 4225 Monterey Avenue.

SHARPE, B. M. (A) service manager, Stanley W. Smith, Inc., 430 23rd Avenue, *San Francisco;* (mail) 1625 Van Ness Avenue.

SMITH, CLIFFORD WILLIAM (J) draftsman, International Motor Co., *Allentown, Pa.;* (mail) 922½ South Eighth Street.

SMITH, HAROLD G. (M) chief engineer, Hercules Motors Corporation, *Canton, Ohio.*

STAMM, A. F. (J) draftsman, designer on fire apparatus, International Motor Co., *Allentown, Pa.;* (mail) 122 South 12th Street.

STONE, BERNARD S. (A) 2007 Third Avenue, *Detroit.*

STROHM, HARRY (M) sales engineer, Wheeler Schebler Carburetor Co., 4-120 General Motors Building, *Detroit.*

SWITZER, RALPH E. (J) layout draftsman, Cadillac Motor Car Co., *Detroit;* (mail) 640 West Willis Avenue.

TAIT, JOHN JOSEPH (F M) chief designer, Argyll Motor Co., Ltd., Bridgeton, Glasgow, Scotland; (mail) 235 Onslow Drive, *Dennistoun, Glasgow, Scotland.*

VAN HOVE, D. H. (M) sales engineer, L. A. Young Spring & Wire Corporation, 9200 Russell Street, *Detroit.*

WEBBER, WILLIAM S. (M) service manager, Checker Cab Mfg. Corporation, 202-218 East 55th Street, *New York City.*

WHITE, JOHN R. (M) superintendent motor equipment and transportation, Standard Oil Co. of New York, 370 Seventh Avenue, *New York City.*

WIGHTMAN, WILLIAM B. (A) supervisor, in charge of vehicular equipment, 18 plants, Bakeries Service Corporation, 502 Wirthman Building, 31st and Troost Streets, *Kansas City, Mo.*

WILSON, JAMES MATTHEW (J) draftsman, LeBaron-Detroit Co., 1551 Harper Avenue, *Detroit;* (mail) 6517 15th Street.

YUAN, TSUNG-TOH (J) student, Massachusetts Institute of Technology, *Cambridge, Mass.;* (mail) 788 Massachusetts Avenue, Suite 9.

Notes and Reviews

AIRCRAFT

Modern Developments in Aircraft Instruments. By C. J. Stewart. Published in *The Journal of the Royal Aeronautical Society*, June, 1928, p. 425. [A-1]

Holding before himself the dictum, "You cannot run the industries of today upon the science of yesterday," the author attempts in a clear summary to present uptodate information concerning aircraft instruments. This is the first paper devoted exclusively to aircraft instruments to be delivered before the Royal Aeronautical Society since a similar treatise was presented four years ago.

The aim of the present paper is to review some of the changes that have been made since publication of the first article; particularly to describe some of the post-war developments in instrument design brought about by the demand for the more accurate measurement of aircraft performance and of conditions surrounding aircraft operation. Redesigning has been called for in almost every case to meet the extension of these conditions, particularly that of temperature. Only the more important and permanent changes are treated in the paper.

Included in the review are instruments of the following types: altimeters, air-speed indicators, statoscopes, climb meters, turning and altitude indicators, thermometers, pressure gages, revolution indicators, fuel flow-meters, fuel contents gages, compasses, and drift indicators.

Notes on Aeroplane Brakes. By H. Bolas. Published in *The Aeroplane*, May 30, 1928, p. 767. [A-1]

Entering upon a controversial and almost virgin field of discussion, the author advances the material of this article as only his personal views on the proper method of brake application.

He dismisses from consideration the hand or foot application from the cockpit on account of the danger of inducing skidding, and narrows his consideration to a comparison of the chassis wheels and the tail-skid as media for automatic braking. His choice falls on the latter, and the next step is to analyze the effect of tail-skid braking quantitatively.

The values involved in tail-skid braking under equilibrium conditions and in a landing run are developed. Experiments to determine the limiting friction coefficient between tire and ground and the friction coefficient of the tail-skid are referred to briefly. The effect upon the landing run of varying the gear ratio between braking and tail-skid load is worked out for a ratio range of 0 to 10, and the conclusion is drawn that in practice the ratio should not exceed 4.

Finally, an examination is made into the conditions under which the brakes may be employed instead of chocks when running the engine while the airplane is on the ground.

Aerodynamic Characteristics of Airfoils—V. Report No. 286. Published by National Advisory Committee for Aeronautics, City of Washington. 44 pp. [A-1]

This collection of data on airfoils has been made from the published reports of a number of the leading aerodynamic laboratories of this Country and Europe. The information which was originally expressed according to the different customs of the several laboratories is here presented in a uniform series of charts and tables.

Each airfoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for designing purposes. The dimensions of the profile of each section are given at various stations along the chord in percentage of the chord length, the latter also serving as the datum line. The shape of the section also is shown with reasonable accuracy to enable one to visualize more clearly the section under consideration, the outside of the heavy line representing the profile.

Traité Pratique de Navigation Aérienne. By A. B. Duval et L. Hébrard. Published by Gauthier-Villars & Co., Paris, France. 128 pp. [A-4]

If aviation is to achieve its commercial majority, according to the thesis of the authors, it must divorce itself as completely as possible from the earth and, independent of ground directions, find its way through its own peculiar element, the air. To achieve the object of navigation, which is to go by the shortest and most convenient route from one place to another, aviation must adapt to its own sphere the technical processes that have served centuries of maritime navigation.

The present volume is a second edition and claims for its first issue the credit of having been the first practical treatise devoted solely to showing aviation how to use navigation's tools. The six chapters incorporated in the book discuss the general rules of aeronautical navigation, the compass, navigation by dead reckoning, navigation by bearings, instruments, and, finally, the practice of navigation. Superfluous and involved mathematics are eschewed.

For the second edition the treatise has been brought uptodate as of March, 1928, and deals with the more recent developments.

Aircraft Radio and Navigation. By Ross Gunn. Published in *The Journal of the Franklin Institute*, June, 1928, p. 849. [A-4]

Radio, which is able, by its very nature, to provide the pilot with valuable information relating to facts exterior to his airplane, doubtless will continue to be a major aid in the development of commercial and military aviation.

This article discusses the essential engineering features of aircraft radio and associated difficulties. Solutions to these problems, based on the thought that simplicity of operation is the ultimate good to be achieved, are given, although no attempt has been made to describe particular equipment.

Two outstanding radio aids to navigation are discussed and a new method is described whereby these may be made to operate a visual indicator in such a way that it will tell the pilot not only whether he is off his course but which way he is off. A heterodyne beacon stated to have certain remarkable directional properties is described.

CHASSIS PARTS

The Wearing Qualities of Tire Chains. By W. H. Parker. Preprint of paper presented before the American Society for Testing Materials. Pub-

(*Continued on next left-hand page*)

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

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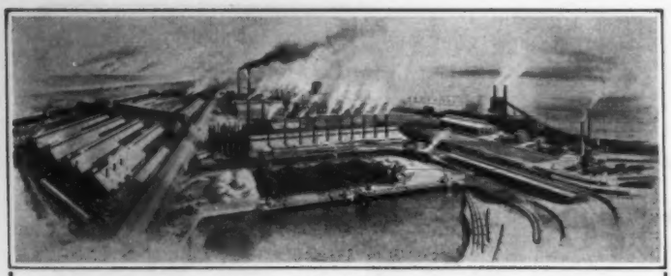

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Notes and Reviews

Continued

lished by the American Society for Testing Materials, Philadelphia. 8 pp.; 5 illustrations. [C-1]

On the theory that the wearing qualities of metals must be tested under conditions related to those of subsequent usage, the author developed an apparatus and procedure primarily for the study of tire-chain material. According to the analysis presented, tire-chain service involves the relation between impact and wear resistance.

In the test devised, the specimen is held at constant pressure against a rotating alundum grinding-wheel, the surface of which is kept continuously dressed. The number of revolutions required to produce a given depth of wear is automatically recorded.

A comparison with service tests indicates that the laboratory test, some results of which are given, rates various materials in virtually the same order as road tests, while giving a much greater distinction between them.

ENGINES

Oil Radiators to Save Big-Ends. Published in *The Motor*, June 12, 1928, p. 888. [E-1]

Fitting an oil radiator was found, in experiments carried out by the Peugeot Co., to reduce the temperature of the lubricant from 195 to 100 deg. fahr. and to decrease its consumption by 15 per cent or more.

As is shown in a diagram accompanying this article, the Peugeot system provides for the delivery of the oil by the pump through the radiator. The oil then goes through a filter to the gallery pipe connected to the main bearings, from which it passes to the big-ends in the usual way. A relief valve is fitted in parallel with the oil radiator, and the thick oil passes to the main bearings through this valve when the engine is started from cold.

The system used on the new six-cylinder Rochet Schneider is described, and another arrangement, recommended for its simplicity, is suggested. An exposition of the conditions that make these oil-cooling systems necessary introduces the descriptions of them. These conditions are increased engine-speeds, the very heavy inertia loads on the big-end bearings and the heated condition of the oil when it reaches these bearings.

An Answer to the Question, Is the High-Speed Two-Cycle Diesel Possible? By P. H. Schweitzer. Published in *Power*, June 19, 1928, p. 1102. [E-1]

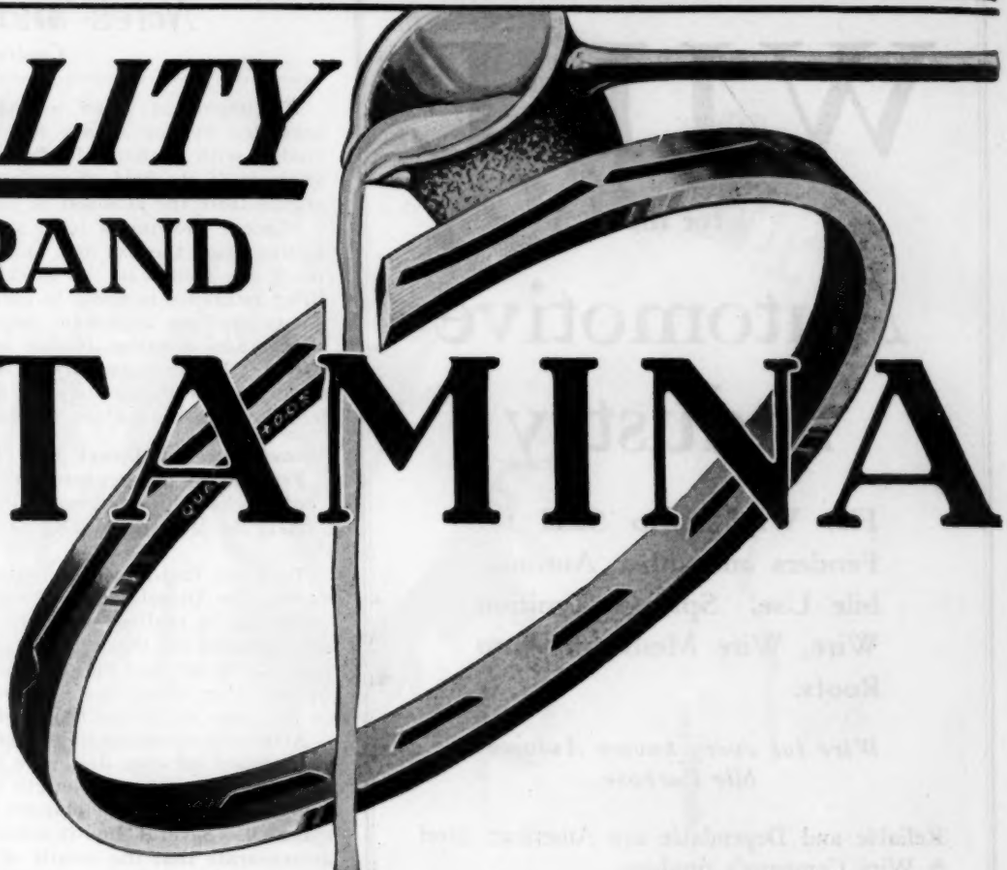
This article presents in skeleton the study made by Dr. O. Holm of the effect of speed on the volumetric efficiencies of properly designed engines of both the two-stroke and the four-stroke cycles. The investigator also endeavored to determine the maximum speeds attainable.

Curves are presented to illustrate the conclusion that in a four-stroke-cycle engine a piston speed of 2750 ft. per min. corresponds with the maximum engine-output. In the more complicated problem of the two-stroke cycle, the effect of varying port heights and charging pressures as well as speeds are considered. This analysis led to the conclusion that the limiting speed is 5500 ft. per min. The volumetric efficiency at the maximum speed was found to be 0.64 with the four-stroke and 0.39 with the two-stroke engine. However, since the two-stroke cycle has double the working strokes for the same number of revolutions per minute, it will still, on this basis of study, exceed the four-stroke cycle in power output if the cylinder dimensions are alike.

The Economic Field for Small and Medium-Size Diesel Engines. By Harlan A. Pratt. Preprint of paper presented before the American Society of Mechanical Engineers. Published by the American Society of Mechanical Engineers, New York City. 6 pp. [E-4]

(*Continued on next left-hand page*)

QUALITY BRAND STAMINA



STAMINA—the power of resistance and the capacity to endure strain is cast into every Quality Brand Piston Ring.

The metal is not distorted by peening, hammering or heat treating. The molecular composition is neither strained nor fractured from the time it is cast.

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Notes and Reviews

Continued

An important place in industry and transportation is predicted by the author for the Diesel engine, which he credits with a thermal efficiency of 33 per cent. In this analysis of its field of usefulness, he considers the Diesel engine from the smallest to the 500 or 600-hp. size.

Figures showing a total saving of $30,000 per year resulting from the use of a Diesel instead of a steam power-plant are quoted in the discussion of marine applications. Brief reference is made to automotive and airplane experiments, and an important foothold in locomotive, rail-car, shovel and dragline bucket operation is claimed for the Diesel. Power costs are given and fundamental factors affecting the desirability of installing Diesel engines are laid down in the section on stationary service.

Manufacture of Diesel Fuel Injectors. By C. R. Alden. Preprint of paper presented before the American Society of Mechanical Engineers. Published by the American Society of Mechanical Engineers, 5 pp.; 6 illustrations. [E-5]

To meet fuel-injection requirements is a difficulty ever facing the Diesel-engine designer. The extreme accuracy called for is realized when these facts are considered; the time allowed for the injection of fuel is frequently not more than 1/240 sec. and an error in metering of 0.000017 lb. per impulse may cause one cylinder to carry 10 per cent more or less than its proper share of the load.

After advancing examples of the often-regretted lack of cooperation between designers and builders, the author cites tests showing that the length of bushing necessary to prevent leakage around a plunger is much less than is usually specified. Several fuel-injection designs are illustrated to demonstrate that the details of such devices have a decided effect on difficulties in assembly and in service. The characteristics of materials from which such parts can be manufactured are given, and ways in which standardization might be applied are suggested.

HIGHWAYS

Report of a Survey of Transportation on the State Highways of Vermont. By the Bureau of Public Roads and the Vermont State Highway Department. Published by Bureau of Public Roads. 80 pp.; 26 illustrations. [F-4]

With this report another volume is added to the library of practical information on road and traffic conditions that is being built up by the Bureau of Public Roads in cooperation with various State highway departments.

As has been the case in States previously surveyed, the Federal-aid-system routes of Vermont bear the burden of the traffic. The roads in this class constitute only 7 per cent of the total mileage, yet they carried in 1926 approximately one-half of the total rural traffic. The State-aid roads are also heavily traveled, while the town roads which make up 69.4 per cent of the total mileage, carry only 12.8 per cent of the total traffic. Other points emphasized as of special interest in connection with the Vermont survey are the comparatively small amount of truck and motorcoach traffic, the large proportion of foreign passenger-cars using the State roads, and the decided seasonal variation in highway transportation.

Much interesting detail as to the types of vehicle traveling the highways, the character of usage, and the length of travel is included in the report.

MATERIAL

A Study of the Production of Chromium Surfaces for Retarding the Corrosion of Nickel at High Temperatures. By George F. Sager. Engineering and Science Series No. 20. Published by Rensselaer Polytechnic Institute, Troy, N. Y. 30 pp.; 13 illustrations. [G-1]

In seeking the fulfillment of an old need—spark-plug electrode material of high melting point, thermal conductivity

(Continued on next left-hand page)

The Function of a Radiator

A radiator serves a very important purpose by controlling the temperature of the motor within safe limits, sufficiently low to prevent overheating and yet high enough to insure proper combustion of gases Heat, of course, is power, but the gasoline can only utilize a small portion of this power The remainder is wasted and must be removed quickly or overheating results. Overheating causes expansion of pistons and bearings, which, if not controlled, results in serious damage Cooling systems by keeping water in circulation and exposed to the flow of air, absorb the surplus heat, passing it off into the surrounding air Radiators being made of brass or copper are so designed to distribute the water in small units over a large area, quickly dissipating the heat, returning the water to the engine to again continue the cycle as described above

Sales Manager: "Our new model has a McCord radiator, the same as all previous models for the past 14 years. The name McCord is assurance of satisfactory cooling, of a dependable unit, equal in life to that of the car."

Salesman: "Did McCord design this radiator?"

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Speed With Ease
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With traffic eight cars wide on the Boulevard, with racing motors ready to jump at the signal light like horses at the post, what other Clutch has responded like the Borg & Beck?

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Notes and Reviews
Continued

and resistance to corrosion by the hot combustion-gases—the investigator here reporting turned to a process that is comparatively new to commercial practice, chromium-plating.

Nickel, the material now generally used, fulfills the first two requirements fairly well. However, it is subject at high temperatures to considerable attack by sulphur dioxide, carbon monoxide and other corrosive gases. Will a chromium or nickel-chromium surface layer satisfactorily retard the corrosion of the wire, yet not appreciably lower its thermal conductivity? was the question the investigator set out to answer.

Three methods of producing the protective coating were examined: (a) the electrodeposition of chromium, (b) the diffusion of chromium into the nickel surface, and (c) the rolling and drawing of a duplex wire from an ingot having a nickel core and a nickel-chromium surface layer. The results of the second process were found to be superior to those of the first. The third method was not sufficiently investigated to warrant judgment.

The Static and Fatigue Properties of Some Cast Irons. By J. B. Kommers. Preprint of paper presented before the American Society for Testing Materials. Published by the American Society for Testing Materials, Philadelphia. 24 pp.; 15 illustrations. [G-1]

The University of Wisconsin, with the cooperation of manufacturers, has just completed the testing of 10 series of cast irons. Included in the investigation were tension tests on two different sizes of specimen, compression, impact, transverse, Rockwell and Brinell hardness, and fatigue tests. The properties of two high-strength cast irons are discussed, and the effects of nickel and chromium additions are pointed out.

Comparisons of the several properties of the irons reveal that, while the fatigue-endurance limit of cast irons can be roughly estimated from properties such as tensile strength, hardness and modulus of rupture, knowledge of the effect of available factors in influencing the properties of cast iron is so meager that such approximate estimates of endurance limit should always be checked by direct experiment. No consistent relation was found between endurance limit and chemical composition.

The author suggests the need of further study along several lines, such as influence of melting and pouring temperatures, heat-treatment of castings, and effect of alloy additions.

Influence of Corrosion Accelerators and Inhibitors on Fatigue of Ferrous Metals. By F. N. Speller, I. B. McCorkle and P. F. Mumma. Preprint of paper presented before the American Society for Testing Materials. Published by the American Society for Testing Materials, Philadelphia. 8 pp.; 3 illustrations. [G-1]

Ordinary corrosion and corrosion-fatigue are compared in this paper with respect to the factors involved. Experiments are then described that showed the effect of inhibitors on corrosion-fatigue with and without other external influences tending to accelerate corrosion.

For the water and the steel used, a small quantity of sodium dichromate is shown to prevent the lowering of the air-fatigue limit by corrosion, but where a strong tendency to pitting is introduced a much larger quantity of inhibitor fails to prevent a serious reduction in the endurance limit. However, inhibitors do tend to increase the useful life of the metal under fatigue by retarding the action of localized corrosion.

Further experimental work on this subject is planned.

Testing of Materials at Elevated Temperatures. By P. G. McVetty. Preprint of paper presented before the Amer-

(*Continued on next left-hand page*)

Nothing is apt to cost so much as a bearing that cost so little

You men who plan, build, use or pay for machines of any kind, remember this: It costs more to replace a poor bearing than to buy the best one that SKF ever produced. AND SKF ANTI-FRICTION BEARINGS ARE THE HIGHEST PRICED IN THE WORLD.

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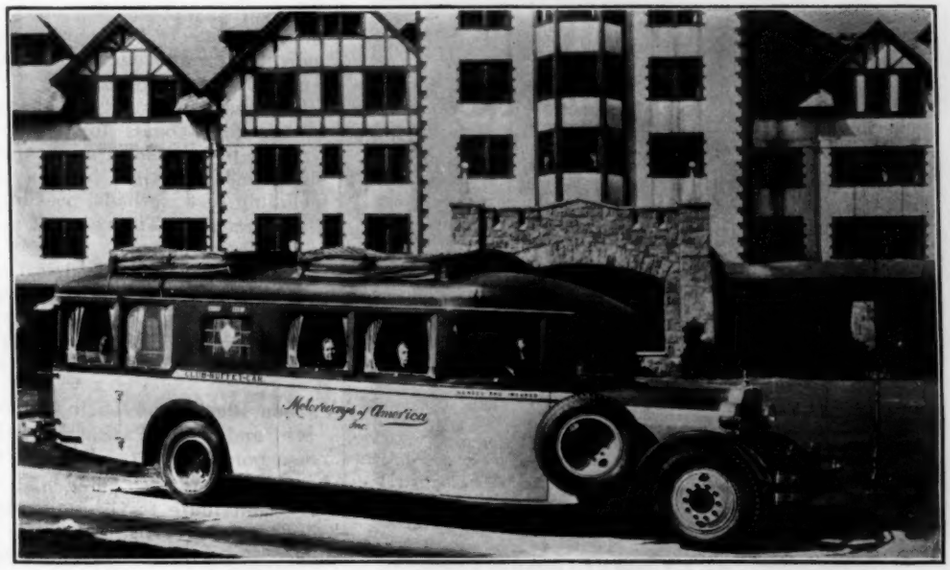

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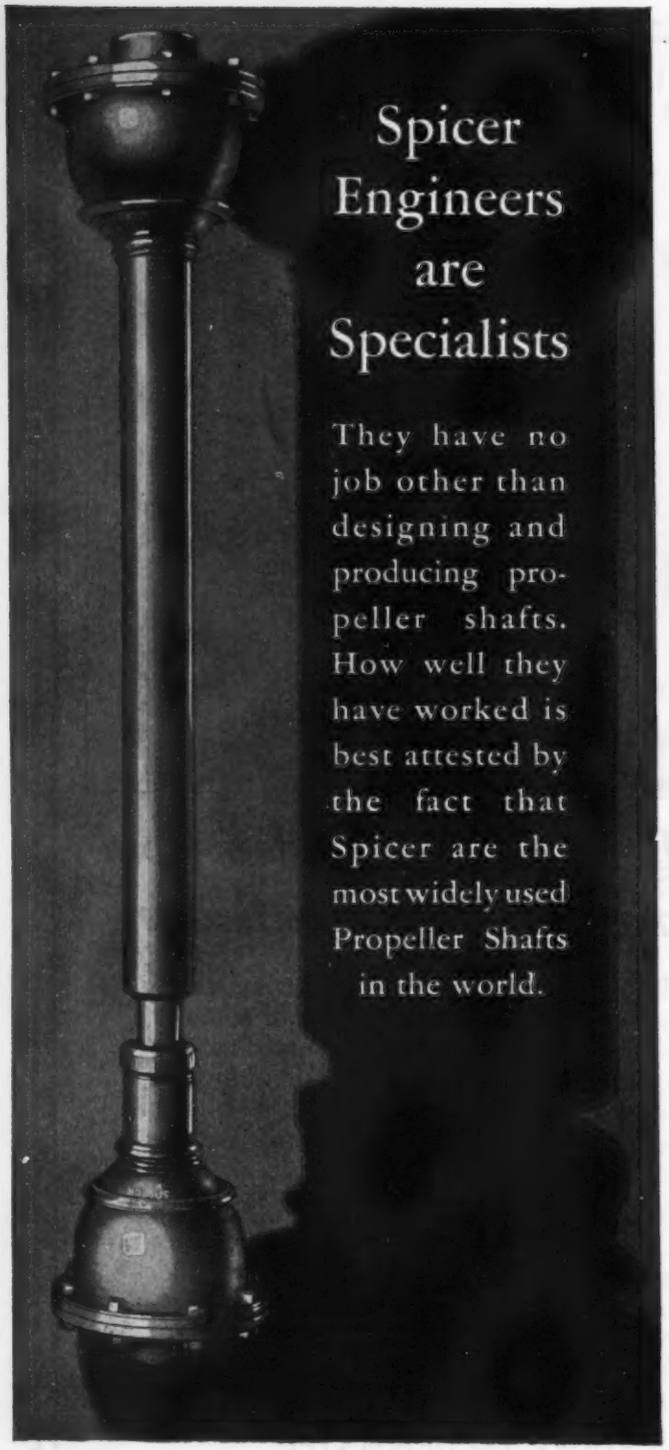
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Notes and Reviews

Continued

ican Society for Testing Materials. Published by the American Society for Testing Materials, Philadelphia. 17 pp.; 4 illustrations. [G-1]

A large number of alloys varying widely in properties and cost have been developed to meet the growing demand for materials to be used at high temperatures. A need is indicated for thorough knowledge of methods of testing materials for such service.

This paper deals with the general subject of materials testing as a basis for choice of materials and working stresses to be used in applications at elevated temperatures. Short and long-time tension tests are discussed in detail, including test methods, possibility of errors, and interpretation of results. The value of accelerated tests as a basis for design is estimated.

The conclusion reached is that carefully conducted short and long-time tension tests with precision temperature-control and strain measurement appear to be the most reliable basis for the choice of materials and of safe working stresses for service at elevated temperatures.

Carbon Blacks and Their Use in Rubber. By Norris Goodwin and C. R. Park. Published in *Industrial and Engineering Chemistry*, June, p. 621; July, 1928, p. 706. [G-1]

To contribute to the understanding of the principles involved in the preparation of rubber compounds was the object of the investigations reported in this article. Belief that the lack of systematically arranged information is responsible for the incompleteness of the knowledge on this subject decided the authors to concentrate in their research on a narrow sector of the general field.

Their work consisted of investigating the physical and chemical characteristics of several carbon blacks and of rubber stocks containing them to determine their suitability as pigments in tire-tread stocks. Five blacks have been studied: Charlton lampblack, Micronex, Super Spectra, Thermatomic, and Goodwin. Part 1 represents a study of the properties of the blacks themselves and their use in raw rubber. Part 2 discusses their action when compounded in cured-rubber stocks containing various accelerators, as mercaptobenzothiazole, diphenylguanidine, hexamethylenetetramine, ethylidene-aniline, litharge, and a base mix of rubber and sulphur.

The Volatility of Natural Gasoline. By G. G. Oberfell. Published in *National Petroleum News*, May 23, 1928. p. 88. [G-1]

Too great rather than too little volatility is the bugbear of the natural-gasoline industry. With automobile carburetters universally adjusted for refinery gasolines, vapor-locking becomes the limiting factor in defining the quantity and quality of the natural gasoline that can be blended in motor fuels offered for sale.

To avoid confusion in his discussion of natural gasoline, the commercial brands of which vary widely in their characteristics, the author considers the butane-free gasoline that the industry is capable of producing, which is a relatively constant material. This product is shown to be a good aviation and cold-weather automobile fuel, from the viewpoint of volatility, vapor-locking characteristics as judged by vapor pressures, and antiknock property.

Since whatever objectionable "wildness" natural gasoline possesses is due primarily to the butane and in a lesser degree to the propane included in it, the author's next step is to consider the effect of varying amounts of such substances in natural gasoline.

Rational specifications for natural gasoline, he concludes would be the Engler characteristics above 100 deg. fahr., with the distillation loss plotted on the front and plus vapor pressure.

(*Continued on next left-hand page*)

SRB Double Row Lubri-Seal Ball Bearing

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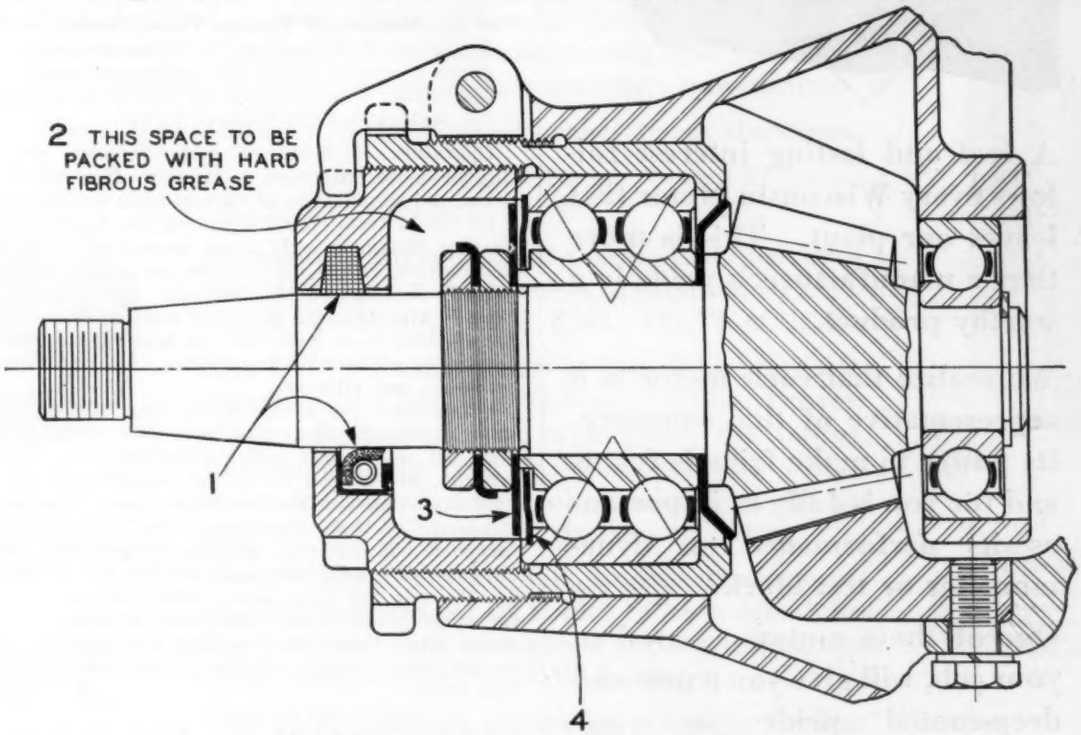

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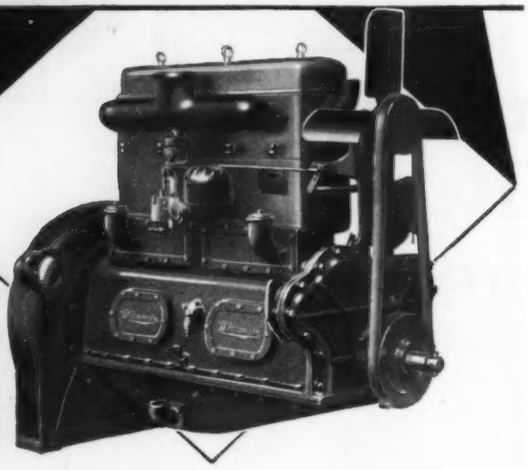

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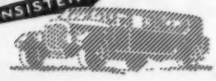

Notes and Reviews

Continued

The Viscosity-Gravity Constant of Petroleum Lubricating Oils. By J. B. Hill and H. B. Coats. Published in *Industrial and Engineering Chemistry*, June, 1928, p. 641. [G-1]

With the present wide variety of crude petroleums and the corresponding diversity of lubricating oils made from them the simple classification between paraffin-base and naphthene-base oils is no longer adequate. It is frequently desirable to indicate the degree to which a particular oil or group of oils is paraffinic or naphthenic.

A mathematical relation has been worked out between Saybolt viscosity and specific gravity from data previously published on the physical properties of the viscous fractions from various types of crude petroleum. The relation is a logarithmic one and expresses the specific gravity in terms of the viscosity and a constant which is different for each crude and is characteristic of it. This "viscosity-gravity constant" is low for the paraffinic crudes and high for the naphthenic crudes. Its value for any oil is a direct index of the degree of the paraffinic or naphthenic character possessed by the oil.

The Significance of Various Tests Applied to Motor Oils. By Robert E. Wilson and D. P. Barnard, 4th. Preprint of paper presented before the American Society for Testing Materials. Published by the American Society for Testing Materials, Philadelphia. 12 pp. [G-4]

Operators of fleets of motor-vehicles will find light thrown in this paper on a question often raised by them—the actual significance of various tests applied to motor oils.

Of the 12 tests standardized by the American Society for Testing Materials, only three, according to the analysis of the authors, reveal information on properties that are important in service: the viscosity and temperature coefficient of viscosity, the pour test and the carbon-residue test. Satisfactory tests have not yet been devised for two other properties of possible importance in service—resistance to oxidation, and oiliness.

Other tests are allocated to three classes. In the first class, embracing those that have little relation to performance but which may indicate contamination or inadequate refining, are placed the color, water and sediment, neutralization number and corrosion tests. The second class, comprised of those that have little or no bearing on performance but that may indicate the probable source of the oil, includes gravity and flash and fire tests. Of least value are those in the third class, which includes tests designed for other products and sometimes injudiciously applied to motor oils. Under this heading are grouped the sulphur-content, unsaturation, emulsion, evaporation and precipitation tests.

Polish Essential for Chromium-Plate. By Charles H. Eldridge. Published in *The Iron Age*, June 14, 1928, p. 1680. [G-5]

Now that interest in chromium-plating has advanced from the theoretical to the practical stage, this article, presenting leaves of experience torn from the notebook of the General Chromium Corporation, will receive its due measure of attention.

Lathe speeds for various operations are recommended. Pointing out that chromium-plating will not only exactly reproduce all the underlying polishing marks but actually magnify them, the author tells of the care that must be taken in preparing the following types of material: pressed steel-sheet, as used for radiator shells; rough-cast or forged steel, for example, bumper material; brass castings; nickel and copper-plated surfaces; and soft die-cast metal, white metal and nickel brasses. Chromium buffing or coloring, unfamiliar to most operators, is described.

(*Continued on next left-hand page*)

Years Ahead On Everything Else *BUT* . . . . Years BEHIND On Filtration

(Unless, that is, you are equipped with the H-W Filtrator)

Year after year new models appear, their manufacturers claiming, and proving their claims, to new beauty of line, new luxury of upholstery and appointments; new standards of performance, new economies, new comforts, new luxuries.

There came balloon tires, four-wheel brakes, shock absorbers.

But the old warning "Change Your Oil Every 500 Miles" persisted.

No manufacturer claimed that he had overcome one of the greatest problems of them all—POSITIVE, PERMANENT OIL FILTRATION.

The H-W Filtrator claims to have achieved these things. And it has PROVEN every claim. Proven them where the going is toughest, the testing hardest and the risk of failure greatest; where miles are dollars and broken schedules run up costs by the minute—on trucks and buses.

Now Western Air Express, known throughout the flying world for its ability to keep schedules for both air mail and passenger service, equips all its planes with the H-W Filtrator.

For H-W Filtrator pioneered scientific "in-line" filtration, placing the non-disintegrating filtrator element between the oil pump and the bearings, affording initial and continuous protection to the finely finished surfaces of the crankshaft and bearings—ELIMINATING COSTLY REPLACEMENTS of filtration medium.

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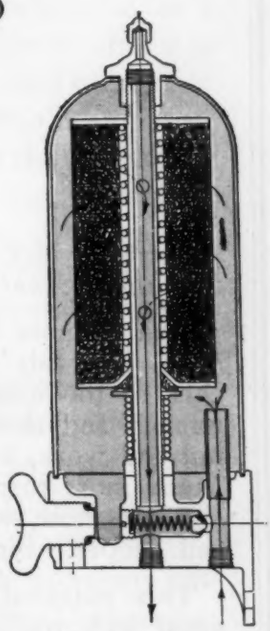

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You can now secure Filtrator-equipped engines on the following: Hall-Scott, Hercules, Continental, Waukesha, Buda and Wisconsin

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Remove the nut, fit compressed air hose to the valve—and the pressure rids the filtering medium of all impurities, which are blown out of the drain opening

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Automotive engineers will be vitally interested in the Watson Oil-Rite System, a new and better lubrication system which easily doubles engine life.

The essential features of the Watson Oil-Rite System are the following:

Keeps lubricant permanently free of abrasives, fuel, acid, water, sludge. Applies oil copiously at the initial starting period. Regulates oil supply while running. Heats oil promptly on starting of engine. Keeps oil cooled under top temperature operating conditions.

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A Turn of the Wrench and it's on to Stay

Here's a lock washer rightly named. It is *shake proof* in fact. Here's why:

Ten or more *twisted* teeth are set at equal intervals around the circumference of the washer. One turn of the wrench and those teeth bite into both nut and work, forming a *positive* lock. Many more turns and twists of *vibration* and those twisted teeth bite deeper and deeper. Simple, isn't it?

This patented and genuinely *shake proof* lock washer is used upon large and small work in hundreds of different lines—making better connections and cutting production costs because it is *tangle proof*. Write today for free samples. Just tell us kind and size of work.

"NOT A TANGLE IN A TON"

Type 12 Internal Teeth — Type 15 Countersunk — Type 11 External Teeth

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Notes and Reviews

Continued

MISCELLANEOUS

Engineers. Published by the Neo-Techni Research Corporation, New York City. 1438 pp. [H-1]

An unusual combination of the theoretical and practical that is calculated to enhance and broaden its usefulness as a handbook characterizes the volume Engineers. The theoretical is represented by collections of fundamental engineering data; the practical, by classified lists of companies manufacturing articles of interest to engineers, together with the names of the chief officers and engineers. Information of both of these types is contained in each of the four sections devoted to the four classes of engineering—civil, electrical, mechanical, and mining and metallurgical—while a fifth section contains miscellaneous data.

The excellence of the engineering material may be judged from the names of those in charge of its collection: Prof. Albert Sauveur, Harvard University, editor-in-chief; Prof. C. L. Dawes, Harvard University, electrical engineering; Prof. H. M. Boylston, Case School of Applied Science, chairman, division of mining engineering; Prof. H. M. Turner, Harvard University, civil and hydraulic engineering; George V. Gwyn, consultant engineer, railroads; G. C. Eaton, Edison Electric Illuminating Co., mechanical engineering; and Charles E. Lehr, chief engineer, Bethlehem Steel Co.

The handbook data are complete, carefully selected and edited, and arranged for the greatest convenience of use. The company listings include 38,335 corporations and 220,600 men connected with them.

Transmissive Power and Stretch of Belting. By C. A. Norman and G. N. Moffat. Engineering Experiment Station Bulletin No. 41. Published by Ohio State University, Columbus, Ohio. 32 pp.; 37 illustrations. [H-1]

The practical belt user must know three things: (*a*) how much power a belt will transmit and to what tension it must be subjected to transmit this power; (*b*) how much and how rapidly the belt will stretch; and (*c*) how long the belt will last and what it will cost in acquisition, upkeep and replacement.

In the piece of belt-research here chronicled the first two questions were investigated on rubber, balata, stitched canvas, oak-tanned and mineral-tanned leather, hair and solid-cotton flat belts, and on a V-belt rubberized. The pulleys used were standard cast-iron, special cast-iron, special sheet-steel, and wood pulleys with iron spiders.

The first runs were made at a speed of 2400 ft. per min., with effective pulls varying from 15.2 to 49.5 lb. per in. of width. After the initial tests the belt was run for 9 hr. under an effective pull of about 35 lb. per in. of width at a speed of about 2400 ft. per min. The runs at this speed and varying loads were then repeated as nearly as possible under conditions identical with those pertaining to the new belt. After this, the speed was increased by steps to a little more than 4800 ft. per min. at the maximum effective pulls that could be used with the equipment.

Besides testing the performance of the belts, the investigation had for its second object the determining of the reliability of tests of the transmissive power of a running belt by means of a static slip-machine.

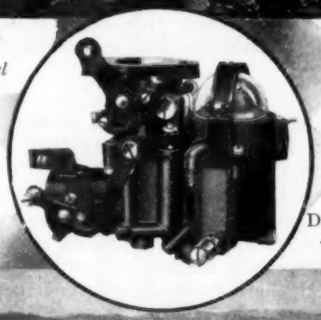
Standards Yearbook, 1928. Bureau of Standards Miscellaneous Publication No. 83. Published by Bureau of Standards, City of Washington. 399 pp.; 18 illustrations. [H-3]

What is the basis of fact for the general impression that in this age the movement for standardization is particularly potent and widespread? To answer this question, not only for this Country but for foreign countries, and not only for the sphere of Governmental activities but for the realm of trade associations, is the object of this, the second, issue of the Standards Yearbook.

(*Continued on next left-hand page*)

Consistent in good performance

PIKE'S PEAK
14,147 ft. above sea level



DEATH VALLEY
310 ft. below sea level

THE engineer specifying a carburetor for a year's series of motor cars knows that it is not the performance of one or two cars—not the results obtained from a week's horsepower tests on the dynamometer under the delicate adjustment of a skilled operator that determines the desirability of a certain type carburetor—but good performance from thousands of carburetors—both foreign and domestic, winter and summer.

Good performance on the same adjustment in Death Valley and up Pike's Peak won Stromberg Plain Tube Carburetors the favor of the production, service, sales and engineering departments of conscientious manufacturers.

The latest development of the Stromberg laboratories is the Model "U" Syringe Carburetor.

Designed to provide maximum power and speed, as well as extraordinary smooth operation when engine turns over slowly.

The ingenious pump attachment (called the Syringe) gives that quick, snappy acceleration that is the delight of the modern motorist.

Excellent performance without sacrificing economy in fuel consumption.

Allow us to give you a demonstration.

STROMBERG MOTOR DEVICES CO., 58-68 EAST 25th STREET, CHICAGO

STROMBERG CARBURETOR

"The Accepted Standard"

"Service at its best— with lower stamping costs"

"Put It Up to Danly"

"Telegraph Danly right away. Tell them we need seven C4 die sets here in 48 hours," said the superintendent.

"That's easy," said the tool room foreman, "and it gets us out of a bad fix. Danly carries them in stock. They'll ship express today."

"Yes," said the super, "and we save over 40% in first cost."

"What I like about Danly is that they keep their word. Those die sets will be here on time, completely assembled, ready for immediate use," said the tool room foreman, thinking ahead. "And what's more, we can mount the die in half the time because all working surfaces are machined."

Yes, you can always depend upon Danly—for quality, for speed. Danly Die Sets reach you assembled, ready for immediate use . . . precision tools. The more you investigate Danly Die Sets, the more you will appreciate the design, materials and workmanship. And the more you use them the more you save.

Got your copy of the new Danly Catalogue, over 100 illustrations, and blueprints, a valuable treatise for every designer, executive? Send for your copy.

DANLY MACHINE SPECIALTIES, INC.

2120 S. 52nd Avenue, Chicago

Detroit, Michigan
1537 Temple Ave.

DANLY STANDARD

Long Island City, N. Y.
36-12 34th St.

DANLY

Die Sets—Leader Pins—Bushings—Dowel Pins—Stripper Bolts—Pressure Pad, Stripper Plate and Knock-out Springs—Socket Head Cap and Set Screws—Shanks—Laps—Bolster Plates.

Notes and Reviews

Continued

An outline is given of the activities and accomplishments of each standardizing agency referred to, with special emphasis on its accomplishments during 1927 and its program for future work. Among the organizations whose work is so summarized are 14 international and 24 National standardizing agencies. A chapter is devoted to the participation in standardization movements of more than 50 Government bureaus in this Country, and another to the Bureau of Standards, which is credited with having made investigations on 42 different commodities.

The extent to which standardized specifications govern the purchasing departments of cities, counties and States in this Country is shown, and the activities of four general standardizing agencies are discussed. The organization and aims of about 300 technical societies and trade associations are outlined in the chapter devoted to this subject. A 20-page bibliography and a discussion of the standardizing of measurement conclude the book.

Electricity and the Motor-Car. By F. H. Hutton. Published by Iliffe & Sons, Ltd., London, England. 135 pp.; 110 illustrations. [H-3]

The object of the author of this small volume is to give, in the simplest possible language, some account of the electrical apparatus used on cars, omitting theories, avoiding technicalities and confining the subject to what may fairly be included under the title of Electricity and the Motor-Car. The book is of interest as an indication of what is thought to be necessary knowledge for the owner-drivers of Great Britain.

In subject matter, the volume covers the first principles of electricity and the theory of operation and care of the magneto, ignition parts, accumulators, and lighting and starting systems. The electric transmission is dealt with briefly and electric accessories are enumerated and illustrated.

Representative Industries in the United States. Edited by H. T. Warshow. Published by Henry Holt & Co., New York. 702 pp.; 59 illustrations; 10 charts. [H-3]

This book is constituted of 22 papers, each dealing with an important American industry. The authors are men who have helped in the development of industry, who understand its processes, and are really an integral part of the development. Of interest to the automotive engineer are the chapters on the aluminum, automobile, chemical, cotton, electrical, leather, lumber, petroleum, zinc, paint, rubber, iron and steel, and blue-lead and mixed-metals industries. Other chapters deal with the banking, construction, copper, meat-packing, water-power and wool industries. Papers on the following topics are also included: history of railroad equipment and non-ferrous metal statistics.

The contributions follow a uniform outline and cover a brief history of the industry, the conditions surrounding its origin, its relation to American industry, its domestic and export trade, its technological processes, its labor problems, its large mergers, and any special developments peculiar to the individual industry.

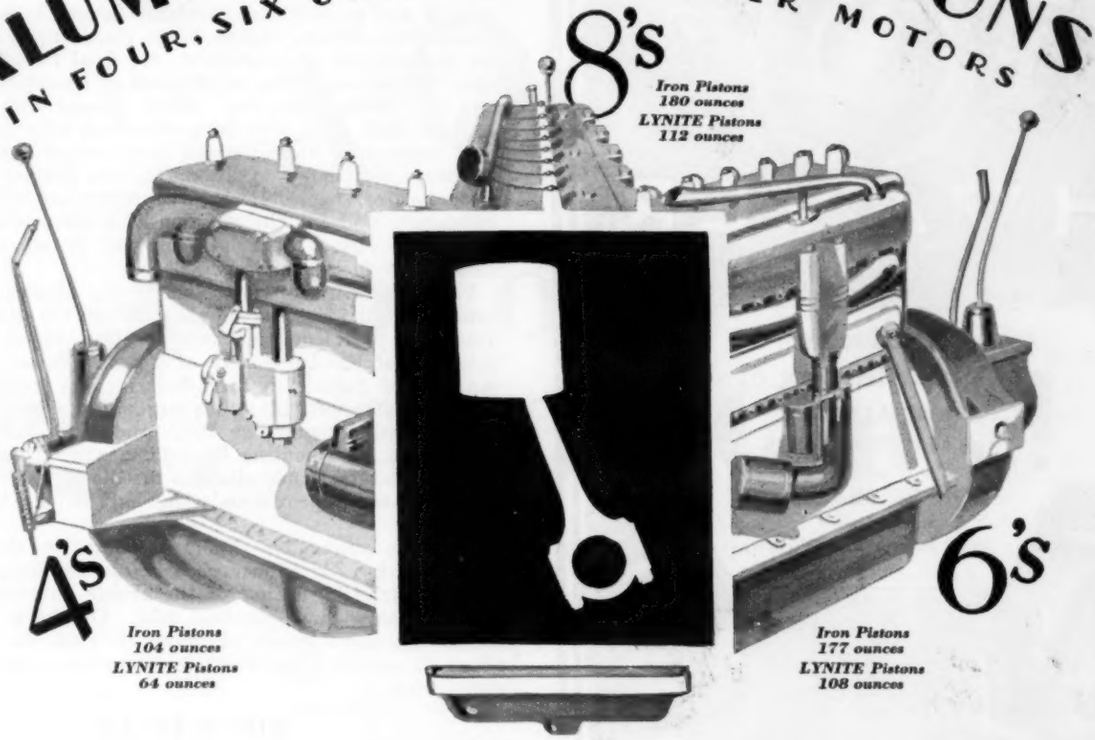
In his paper on the aluminum industry, Robert J. Anderson, consulting expert on aluminum, shows that the manufacturers of automotive vehicles and aircraft are large users of aluminum or aluminum alloys. At present 40 per cent of the aluminum consumed in this Country is employed in the automobile industry, the author points out, and 15 per cent is used for miscellaneous purposes, such as for aircraft, chemical-plant equipment, paint and foil. A chart accompanying his paper shows the relation between the domestic aluminum and the automotive output for the period from 1882 to 1926.

A. R. Erskine, of the Studebaker Corporation of America, discusses in his article on the automobile industry, its trend,

(*Concluded on next left-hand page*)

ALUMINUM ALLOY PISTONS

IN FOUR, SIX OR EIGHT CYLINDER MOTORS



Plain Arithmetic Proves the Superiority of

LYNITE
PISTONS AND RODS

Lightness of reciprocating parts is a major factor in the development of horsepower. The three examples pictured above illustrate the decided advantage of LYNITE over iron pistons and connecting rods. You don't have to be an engineer to figure out the difference. You can feel it in LYNITE equipped cars.

OF THE many improvements which have combined to produce finer motor performance, none have been of greater value than LYNITE Pistons and Connecting Rods.

Four Cylinder Motors **are better when LYNITE equipped because the light weight of these strong aluminum alloys counteracts the natural hesitancy, or "drag". Vibration is reduced to a minimum and the high heat conductivity of LYNITE makes possible higher compression—greater power. Carbon deposits and spark knocks are practically eliminated. That is why LYNITE is *standard equipment* on modern fours in every price class.**

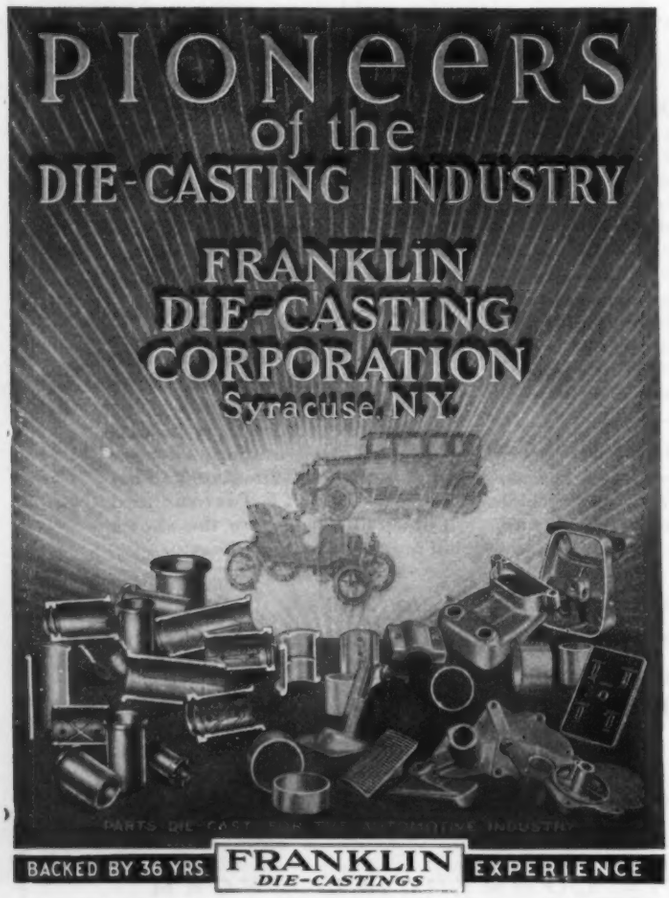
Six Cylinder Motors **are better when LYNITE equipped because the "super-performance" which characterizes the present day six is made possible by the employment of high compression, hitherto regarded as impossible because of the heat which it creates. LYNITE Pistons and Connecting Rods rapidly and completely dissipate this surplus heat. That is why you will find them in the *finest* of sixes.**

Eight Cylinder Motors **are better when LYNITE equipped because compression is high and eight cylinder construction is subject to a slight periodic vibration. The dissipation of heat must be perfect, and the vibration, however slight, must be eliminated. That is why LYNITE Pistons and Connecting Rods are the choice of *leading* manufacturers.**

Just pick out the car that seems to you to have the greatest sales appeal. Whether it is a four, a six, or an eight—you are almost certain to find it equipped with LYNITE Pistons and Connecting Rods.

ALUMINUM COMPANY OF AMERICA
PITTSBURGH, PA.

ALUMINUM - IN - EVERY - COMMERCIAL - FORM



Notes and Reviews

Concluded

outlook and growth, and furnishes figures to emphasize its tremendous strides. Emphasis is placed upon the value of the motor-truck as a substitute for local freight trains and upon the success of the motorcoach as operated by the electric and steam railroads. Other phases with which Mr. Erskine deals are: (*a*) the gains which railroad and insurance companies have derived from motor transport, (*b*) highways and motor taxation, (*c*) the development of the mechanics of the motor-car, (*d*) motor-car regulation and legislation, and (*e*) the addition of a maintenance division to the two great branches common in all manufacture, namely, production and sales.

The significance of petroleum in the development of the automotive industry is emphasized in the paper on the American petroleum industry, written by George Ward Stocking, of the University of Texas. To stress the vast quantity of petroleum furnished for the great American motor-vehicle fleet, Mr. Stocking points out that the refineries of the Country in 1923 produced 7,332,329,000 gal. of gasoline, representing by volume approximately 28 per cent of the total crude oils and distillates run to the stills, and by value approximately one-half of the total refined products.

That the automobile chiefly accounts for the expansion of the market for rubber goods is an explanation, offered by Mr. Litchfield, author of the article on rubber, for the rapid advances made in this field. Of the $1,200,000,000 worth of rubber goods produced in 1926, he states that about 72 per cent represented automobile tires, tubes and accessories.

MOTOR-TRUCK

Goods Transport by Road Motor—Its Financial and Statistical Aspects and Limitations. By J. L. Clewes. Published in *The Journal of the Institute of Transport*, May 1928, p. 355. [K-4]

Motor-trucking is younger in Great Britain than in this Country, according to the estimate made in this article, which gives its age as 6 or 7 years. Its vitality is attested to by the 281,000 vehicles licensed on Nov. 30, 1927, for carriage of goods, as against a total of 22,000 commercial vehicles of all kinds in 1914. Sixty per cent of the 281,000 goods-carrying vehicles are owned by producers, manufacturers and traders.

In the first section of this paper, the author outlines an entire motor-freight-transportation system, based on his own experience with an owner-user's fleet. Concrete cost figures are included as well as the general exposition. In the second section the author compares road and rail costs, pointing out that, according to the figures given, road transportation is 55 per cent cheaper than rail transport for a haul of 20 miles, that the difference gradually decreases as the distance becomes greater, until at 80 miles the advantage crosses over to the rails.

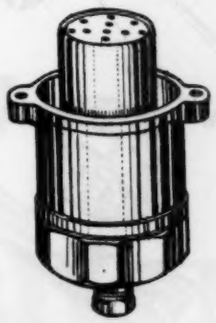
TRACTOR

Substitutes for Breakpins—Drawbar Springs. By E. G. McKibben. Published in *Agricultural Engineering*, June, 1928, p. 167. [M-1]

In examining the conditions under whch drawbar springs may be substituted for breakpins, the author shows by formula and chart the kinetic energy of a moving tractor and the effect of speed on it. The potential energy of a drawbar spring is next analyzed and the relationship between this and the factor first dealt with is established. Embodying a graphic representation of the equations developed is a chart from which can easily be obtained the approximate relationship between weight, speed and tractive ability of tractors and the load-deformation ratios of drawbar springs.

Supplementing the theoretical section, the author describes and examines the action of three typical drawbar-springs. Conclusions as to the field of usefulness of such connections are set forth in 16 clauses.

Proved Out on over 250,000 Cars !



QUICK starting in the coldest weather can now be assured for *your* car . . . *any* car. Over 250,000 cars . . . using both poppet and sleeve valve engines . . . including factory-equipped models of 5 leading manufacturers . . . are daily demonstrating the starting efficiency and dependability of the

AS-KE AUTOMATIC FUEMER

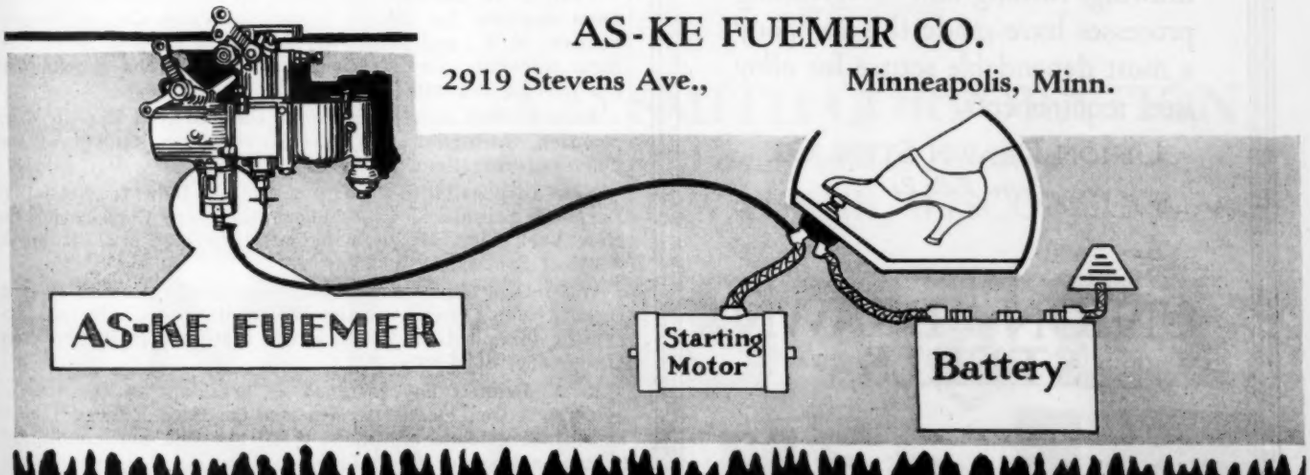
It receives raw gas from the carburetor, vaporizes and heats it automatically into highly explosive fumes. It is simple, fool-proof and entirely automatic in operation. Works with electric current supplied by the regular car battery. Connected by cable to the starting switch so that it goes into action automatically as soon as the starter pedal is operated. Adaptable for all makes of carburetors.

By prompt starting, the As-ke Fuemer reduces the drain of winter starting on the battery and electrical equipment (requires only as much current for each start as is used in burning headlights for 3 minutes), lessens oil dilution, reduces wear and strain on motor, starting gears, etc. . . . insures greater satisfaction to the car owner and fewer complaints and free service demands on your distributors and dealers.

Demonstration arranged at your convenience. Correspondence invited.

AS-KE FUEMER CO.

2919 Stevens Ave., Minneapolis, Minn.



USE THE RIGHT STEEL FOR THE RIGHT PURPOSE

Cold Drawn Alloy Steels *that Meet Exacting Requirements*

THE cold finishing of alloy steels calls for the highest skill that science and long experience can supply.

This organization employs a large technical staff to supervise this difficult production supported by extensive equipment including modern heat treating and annealing facilities.

These resources coupled with thirty-nine years of experience with drawing, turning and straightening processes have made this company a most dependable source for alloy steel requirements.

UNION DRAWN STEEL CO.
Beaver Falls, Pa.

UNION DRAWN STEELS

Personal Notes of the Members
Continued

This year he is an S.A.E. representative on the Joint Illuminating Engineering Society and S.A.E. Steering Committee on Headlight Research.

W. S. Penfield, who until lately was superintendent of shops for the Associated Oil Co. at San Francisco, has accepted a position with the Key System Transit Co., Oakland, Cal., as superintendent of the motorcoach division. His affiliation with the Associated Oil Co. began in 1917.

Elected to Society membership in 1925, Mr. Penfield joined the Northern California Section when it was organized. In 1927 he was elected chairman of his Section. In an interesting paper, entitled Engine Overhauling in Fleet Maintenance, which was published in the August 1926, issue of THE JOURNAL, Mr. Penfield described how often overhauling should be done and what it includes.

W. C. Naylor, balloon pilot of National repute, recently took a prominent part in the Balloon Races. With his entry, the Detroit, he flew 187½ miles in the National Elimination Race, winning third place, and in the Gordon Bennett Cup Race he took ninth place with a flight of 325 miles to his credit. At present chief engineer of the Stinson Aircraft Corporation, he has shown unusual versatility in the field of aeronautics in connection with the manipulation of heavier-than-air and lighter-than-air craft.

Mr. Naylor became a Junior Member of the Society in 1927 and since that time has been an active participant in the aeronautical work of the Society. This year he is Chairman of the Meetings Committee for the Detroit Section Aeronautic Division and is also serving on two subdivisions of the Standards Committee of the Society: the Subdivision on Aircraft Storage-Batteries and the Subdivision on Airplane Wheels, Tires and Rims.

The science of motorless flying or gliding has received a decided impetus in the recent organization of the Evans Glider Clubs of America, with National headquarters in Detroit. Three trophies are now being made to be awarded to winners of the city, State and National contests. **Edward S. Evans,** president and general manager of the Evans Auto Loading Co., Inc., Detroit, and chairman of the Aviation Committee of the Detroit Board of Commerce, is responsible for the organization of these clubs. In 1926 he completely encircled the globe in 28 days, 14 hr., 36 min. and 5 sec., establishing a record that was only broken recently by John Henry Mears and Capt. B. D. Collyer.

Mr. Evans became an Associate Member of the Society and a Detroit Section member in 1924.

C. K. Alexander, of the Wheeler-Schebler Carburetor Co., located in Indianapolis, has assumed his new duties as sales engineer. He formerly acted as district manager in the Cleveland branch of the company.

Prof. F. G. Baender has given up his duties as development engineer for the De Laval Separator Co., of Poughkeepsie, N. Y., and joined the faculty of Oregon State College, Corvallis, Ore., to become head of the mechanical engineering department.

Rura O. Ball, now designer for the Monarch Tractor Corporation, Springfield, Ill., was previously a student at the University of Illinois at Urbana.

New responsibilities have taken **O. Balz** to Germany. Formerly president of the Index Machinery Corporation, in New York City, Mr. Balz is now connected with Hahn & Kolb, of Stuttgart, Germany.

W. McLain Bass was recently appointed salesman for the Omaha, Neb., branch of the White Motor Co. Before accepting this position, Mr. Bass was a student in Washington University, St. Louis.

R. A. Bennett has resigned as president of the Hawkeye Truck Co., located in Sioux City, Iowa. He will continue his residence in Sioux City but has not announced busines splans for the future.

(Continued on next left-hand page)

ENGINEERING FOR ROADABILITY

One reason why the A. O. Smith Corporation is the major source of supply for Automobile Frames today is the contributions that A. O. Smith Engineers have been able to make to the roadability of new models.

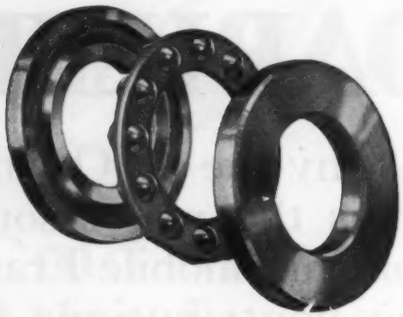
ENGINEERING FOR MASS PRODUCTION

Another reason has been the engineering of mass production machinery by A. O. Smith Engineers that produces better frames at equal or lower costs.

A. O. SMITH CORPORATION
Auto Products Division
MILWAUKEE, WISCONSIN

SMITHSTEEL FRAMES

Precision Beyond Specifications



Automotive Engineers know that each bar of steel that goes into the making of Aetna Thrust Ball Bearings is ordered to strict specifications—that each bar undergoes severe metallographic tests in the Aetna Engineering Laboratories—and that only the finest steel is accepted. Aetna Bearings must give perfect performance.

The modern automobile is a masterpiece of design and construction. Motor power has been increased and smooth operation made a requisite of every moving part. Aetna volume production enables us to take advantage of manufacturing economies—but never have we found it necessary to sacrifice quality for quantity. The strict standards of Aetna manufacture have coined the phrase—"Precision Beyond Specifications."

Our Engineering Department stands ready at any time to consult with any manufacturer in the design of special thrust ball bearings—or to quote on Aetna Bearings as standard equipment. Let us send you the latest Aetna Engineers' Catalog with complete specifications.

AETNA BALL BEARING MFG. CO.

2745 High St., Chicago, Ill.

AETNA

THRUST BALL BEARINGS

NORMAL STEEL
Required for Aetna Bearings. Note the even grain structure.
ABNORMAL STEEL
Not up to Aetna standards. Note the uneven grain structure.

Personal Notes of the Members

Continued

John A. Bishop, until lately supervisor of motor-vehicles with the Socony Burner Corporation, New York City, has become associated with the Standard Oil Co. of New York in the capacity of office manager in the maintenance division.

J. E. Bourne, a former student at the Massachusetts Institute of Technology, will enter the service of the Ingersoll-Rand Co., at Phillipsburg, N. J., on Sept. 15.

Herbert C. Colburn is now aeronautical engineer for the Aircraft Engineering Co., Los Angeles. Prior to establishing this connection, he was general manager of the Colburn Radio Laboratories, of San Francisco.

Formerly metallurgist for the Titusville Forge Co., of Titusville, Pa., **Glenn Coley** recently formed an affiliation with the Detroit Edison Co., Detroit, his new position to be in the power sales department.

Edward W. Dart, formerly experimental engineer at the automotive laboratory of the Texas Co., Bayonne, N. J., has become a member of the engineering staff of the Metal Aircraft Corporation, of Cincinnati.

G. R. Davenport has left the Studebaker Corporation, South Bend, Ind., where he held the post of special engineer, to act in a similar capacity for the Graham-Paige Motors, Detroit.

Livingston Disbrow lately became associated as draftsman with the Bellanca Aircraft Corporation, Staten Island, N. Y. He was previously designer for the International Motor Co., Long Island City, N. Y.

F. A. Dodge, in accepting the position of general sales manager of the W. G. Nagel Electric Co. at Toledo, Ohio, renews an affiliation which lasted two years, dating back to 1924. In the interim Mr. Dodge was vice-president of the J. C. Haartz Co., of New Haven, Conn.

A. L. Doerr, formerly special representative of the General Motors Truck Co., Detroit, has been transferred to the General Motors Export Division. Mr. Doerr sailed last June 14 to join the truck and bus division of General Motors (Australia) Proprietary, Ltd., located at Melbourne.

James L. Endicott recently resigned his position as chief engineer in charge of production of the Elgin Oil Burner Corporation, City of Washington, to become manager of Maurice J. Colbert, distributor of Petro oil burners, also in the City of Washington.

Milton W. Franklin, formerly president and general manager of M. W. Franklin, Ltd., in Honolulu, has sold the business and will temporarily suspend engineering activities to take a long-earned vacation in California.

M. C. Frins, chief draftsman in the engineering department of the International Motor Co., has transferred his activities from Long Island City to the Plainfield, N. J., plant of the same company.

Lester D. Gardner, until lately owner and publisher of *Aviation*, has been elected president of Aeronautical Industries, a new company recently organized in New York City for the purpose of providing expert advice and of financing airplane builders and airline operators.

Frank Hadley, who is employed as layout draftsman by the International Motor Co., has been transferred from headquarters in Long Island City, N. Y., to the Plainfield branch.

W. C. Heavrin, who until lately was lubricating engineer with the Standard Oil Co. of Indiana, located in Chicago, is now employed as salesman by the James W. Bell Co., Cedar Rapids, Iowa.

Arthur E. Hutchison is now connected with the Simplex Piston Ring Co. of America, Inc., at Cleveland, in the capacity of Eastern engineer, having resigned his position as service engineer with the Simplex Piston Ring Co. of Brooklyn.

Hudson W. Kellogg, previously timekeeper for the Packard Motor Car Co. of New York, is at present employed

(Continued on next left-hand page)

He Cursed *the* CAR

—But LACK of LUBRICATION *was the REAL Trouble!*

In just 5 minutes you can prevent this injustice to the cars you sell

WE have recently investigated repair bills and service in 45,000 garages, service stations and dealers' service departments. This disclosed too many cases where the owner condemned the car—and inspection showed the trouble due to improper or neglected lubrication.

Avoid this in 5 minutes
—as you sell the car!

Naturally, you impress upon the new owner the performance and merit of the car he buys. Now take 5 minutes more to insure he keeps on getting all the fine service that's built into it. Don't let him drive off until he understands the importance of regular, proper lubrication! Explain the Alemite system to him thoroughly

AND:

Make sure that he comes back to YOU for regular ALEMITE-ING (forcing genuine Alemite lubricant into gears of car—with Alemite equipment).

You cash in two ways

You pave the way to future sales. By guarding against ignorant misuse of the car you sell. And you know from experience that most of tomorrow's sales are built from the performance of cars in use today. This emphasis on Alemite lubrication will go far to make every buyer enthusiastic over your car's performance.

In the second place, you are bringing that owner back once or twice each month for service. Thus you keep in constant touch with him. And this service makes you a net profit of from $12 to $25 per year on each car—your service profit on Alemite-ing!

The Bassick Manufacturing Company Division of Stewart-Warner, 2654 N. Crawford Avenue, Chicago, Ill. Canadian address: The Alemite Products Company of Canada, Ltd., Belleville, Ontario.

ALEMITE
HIGH PRESSURE LUBRICATION

©T. B. M. Co.

Stewart-Warner

THE COMBINED STRENGTH OF THESE TWO NAMES—REPRESENTING THE LARGEST ACCESSORY MANUFACTURERS IN THE WORLD—IS YOUR GUARANTEE OF *QUALITY* ALEMITE

With

NATIONAL
[Double-Action ~ Non-Curling]
SHIMS

you can do BOTH

[(1) Improve motor performance
(2) Cut manufacturing costs]

THESE Motor Manufacturers are DOING IT

DODGE
CHEVROLET
G. M. C.
WAUKESHA
WISCONSIN
CATERPILLAR
CONTINENTAL
HALL SCOTT
TWIN CITY
CLEVELAND TRACTOR
—and others

Motors cease to perform satisfactorily when bearings lose their adjustment. NATIONAL Shims improve motor performance, in that (1) they prevent bearings losing their original factory adjustment (2) they facilitate accurate adjustments in service. They cut manufacturing costs, in that (1) they accelerate accurate bearing assembly (2) they eliminate loss from overstripping (3) they reduce the number of rejects. This combination of advantages is inherently and exclusively NATIONAL, in that (1) NATIONALS are made of *hard* brass, layer on layer, nothing between, and do not compress under bolt pressure (2) they are soldered at the edge *only*, layers are already separated for quicker, easier fitting, no stick, no curl, double action—take off or put back leaves at will. Submit blueprints for prices. Designs and suggestions by our Engineers upon request.

1. Unit (laminated type) shims 2. Babbit-faced shims
3. Steel shims 4. Steel bronze-faced shims 5. Steel liners
6. Copper liners 7. Brass liners

NATIONAL MOTOR BEARING CO., Inc., Mfrs.

DETROIT . . . 222 West Larned Street
SAN FRANCISCO . 460-470 Natoma St.
CHICAGO . . . 30 West Walton Place

Also manufacturers of
STAR LOCK WASHERS

NATIONAL STANDARD PARTS ASSOCIATION NSPA

Personal Notes of the Members

Continued

by the International Motor Co., Plainfield, N. J., his new work consisting of testing engines.

Herman F. Krantz, a former student at the Massachusetts Institute of Technology, lately entered the service of the Otis Elevator Co., at Boston, as a student.

G. W. La Selle, formerly associated with the engineering department of the Erie Steam Shovel Co., Erie, Pa., recently formed a similar affiliation with the Hercules Motors Corporation, of Canton, Ohio.

Robert P. Lay has severed his connection with the Penn Spring Works, of Baldwinsville, N. Y., for which he acted as chief engineer, to become assistant chief engineer of the H. H. Franklin Mfg. Co., at Syracuse, on July 1, last.

Otto Lohmann has announced a change in position and residence. Formerly technical director in the automobile manufacturing department of Mauser-Werke Automobil Gesellschaft, at Oberdorf am Neckar, Germany, he now holds a similar position with Gemeinschaft Deutscher Automobilfabriken G. m. b. H., in Hamburg, Germany.

Arthur Ludwig recently resigned as draftsman with the International Motor Co., Long Island City, N. Y., to accept a like position with the Kennedy, Van Saun Mfg. Engineering Corporation, in New York City.

Marie Luhring, associated with the International Motor Co., Long Island City, N. Y., in the capacity of assistant engineer in the rail-car department, has been transferred to the Pond Plant of the company, located in Plainfield, N. J.

Murray Mantelman has accepted a position as automatic-machine designer for the S. P. Ellsworth Mfg. Co., of Brooklyn, N. Y. Mr. Mantelman previously attended Brooklyn Polytechnic Institute.

Capt. D. G. McGregor, of the Ordnance Department, United States Army, formerly stationed at Springfield, Mass., has been transferred to duty at Fort Leonard Wood, Camp Meade, Maryland.

James D. McMahon, a former student of the University of Detroit, has entered upon the student training course given by the Fisher Body Corporation, of Detroit.

Fritz Mitschke lately established a connection with the Nationale Automobil Gesellschaft, at Berlin, his work to consist of tool designing. Mr. Mitschke has been a resident of Germany since the latter part of March, when he resigned his position as tool designer for the New Brunswick branch of the International Motor Co. to go abroad.

Charles L. Nein became designer for the Ward Motor Vehicle Co., Mt. Vernon, N. Y., on June 1. Prior to his acceptance of this position, he filled a similar post in the International Motor Co., Long Island City, N. Y.

Alling Parkhurst, formerly special representative for the Commercial Truck Co. in New York City, recently established a connection with the Walker Vehicle Co., of New York City.

Louis F. Pietz, a former inspector of the International Harvester Co. of America, Springfield, Ohio, is now associated with the Buda Co., of Harvey, Ill.

Eugene R. Pritchard has announced his new connection with the Walker Vehicle Co. He was previously assistant engineer in charge of special equipment design for the International Motor Co., Allentown, Pa.

Fred Rath, formerly tool designer for the International Motor Co., will serve the Curtiss Aeroplane & Motor Co., Buffalo, in a similar capacity.

Ralph E. Rich is now plant manager of the Auto Accessories Corporation, located at Chicago. Prior to accepting this position he acted as special engineer in the millednut department of the Lamson & Sessions Co., at Kent, Ohio.

Paul R. Riess, following his resignation as New England service representative of the Reo Motor Car Co., last May

(*Concluded on next left-hand page*)

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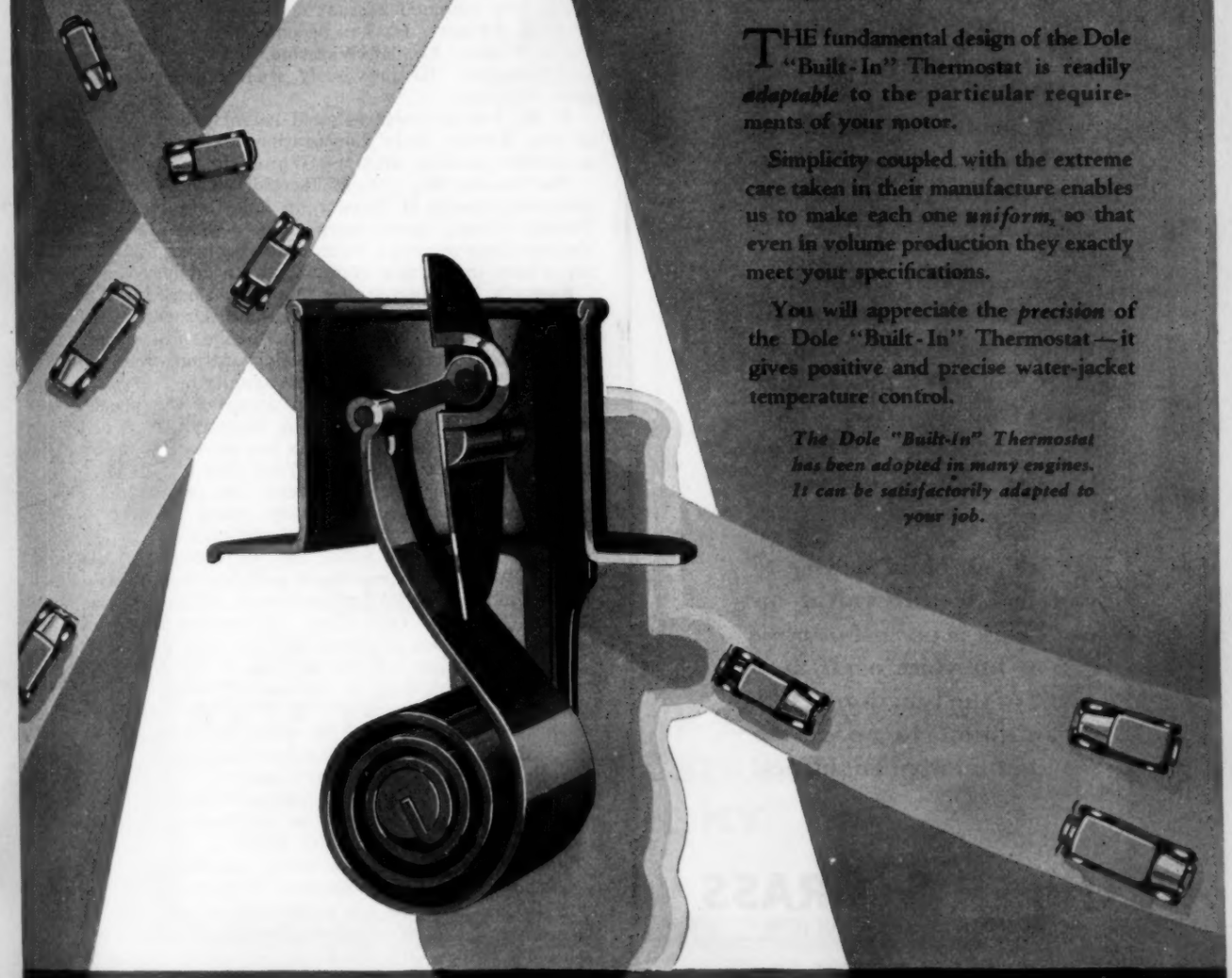

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Personal Notes of the Members
Concluded

accepted the position of service manager for Frank Crook, Inc., in Pawtucket, R. I., Reo distributors for the State of Rhode Island.

V. W. Schlieder, former vice-president and treasurer of the Schlieder Mfg. Co., of Detroit and Milford, Mich., has assumed the secretaryship of a new company formed several months ago by the merging of the Schlieder Mfg. Co. and the Gill Mfg. Co., of Chicago, with the Diamond Motor Parts Co., of St. Cloud, Minn.

Earl C. Smith has given up his position as inspector for the John Warren Watson Co., Philadelphia, to become shop engineer of the International Motor Co., at Allentown, Pa.

J. R. Starr, a Purdue University student, recently joined the Frigidaire division of General Motors, Dayton, Ohio, as a student engineer.

Carl A. Stickel, formerly a member of the engineering staff of the Menominee Motor Truck Co., is now junior patent examiner in the United States Patent Office at the City of Washington.

Horace S. Strong's title was changed on June 1 from specification engineer in charge of engineering records, at the Milwaukee division of the Nash Motors Co., to assistant production manager of that division.

A. M. Swigert, Jr., has become associated with the John Deere Tractor Co., at Waterloo, Iowa, in the capacity of tool designer. He previously studied engineering at Iowa State College.

F. M. Vandervoort resigned recently as design engineer of the Mullins Body Corporation, Salem, Ohio, to accept a similar position with the White Motor Co., Cleveland.

The Veeder Mfg. Co., of Hartford, Conn., founded by its president, **Curtis H. Veeder**, in 1895, and the Root Co., of Bristol, Conn., have merged as Veeder-Root, Inc. Mr. Veeder plans to retire from active business but will remain for a time in the new company in an advisory capacity.

Kenneth W. Warren last January formed an affiliation as design engineer with the LeBlond Aircraft Engine Corporation, of Cincinnati, when the above corporation bought the Detroit Aircraft Engine Corporation, for which Mr. Warren had acted in a similar capacity.

Joseph Wertzheiser recently accepted the presidency of the Radworth Mfg. Corporation, Brooklyn, N. Y. Prior to forming this connection, he was vice-president of the Meteor Electric Corporation, of New York City.

R. R. Whittingham has severed his connection with the Vacuum Oil Co., New York City, where he acted as eastern manager of the commercial-car division, to accept the presidency of Auburn Sales, Inc., at Wilmington, Del.

A. M. Willing has been made technical field representative in the Manila zone, Philippine Islands, of the General Motors Export Co., New York City. He formerly served in the capacity of service engineer for the same company.

James Wills has left the service of the National Biscuit Co. in New York City to become affiliated as designer in charge of drafting with the R. C. A. Photophone Co., also of New York City. In his previous position Mr. Wills was engaged in automatic-machine designing.

Walter A. Wood, previously head of dynamometer tests in the General Motors Corporation Research Laboratories at Detroit, recently joined the engineering department of the Buick Motor Co., at Flint, Mich.

Samuel H. Woods is now acting as manager of the new car department of the General Motors Truck Co., New York City. Prior to his acceptance of this position, Mr. Woods served as an engineer for the International Motor Co., Long Island City, N. Y.

H. A. Zeller, connected with the General Motors Export Corporation, of New York City, recently sailed for Germany to become associated with the foreign branch of the corporation, located at Berlin, Germany.

H. L. Zimmerman has formed an affiliation with the Milwaukee plant of the Nash Motors Co., having resigned his position as sales engineer of the Perfex Corporation, at Milwaukee.

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SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET
NEW YORK, N.Y.

It is a waste of time — *sheer folly* — to work and adjust to get a good ride unless that ride "*stays put*"

If we are working with a resistance medium which is of such nature that it is altered by conditions over which we have no control, the weather for example, we have gotten nowhere after we *have* succeeded in getting the ride we want—for tomorrow the weather is bound to change and the ride will change with it—will be something different, maybe vastly different, from that which we had chosen.

The latest contribution of the Watson Organization is destined to revolutionize all Industry—for Watson has produced, for the first time in the history of industry, a resistance medium, RUBBER FLOW, which is unaffected alike by wet and dry, and also is unaffected throughout any temperature range encountered in service. This newly developed resistance medium will quickly find its way far beyond the realm of "shock absorbers," for all industry is demanding and will welcome a resistance medium which remains unchanged today, tomorrow and every day.

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When you get the ride you want with the new Watson RUBBER FLOW Stabilators—that ride, exactly that ride, will be yours to enjoy every day of the year whether it be Zero January, Ninety-in-the-Shade July, Thawing and Sloppy March, or Glorious October. Now, for the first time, a "ride" is yours on a "stay put" basis.

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